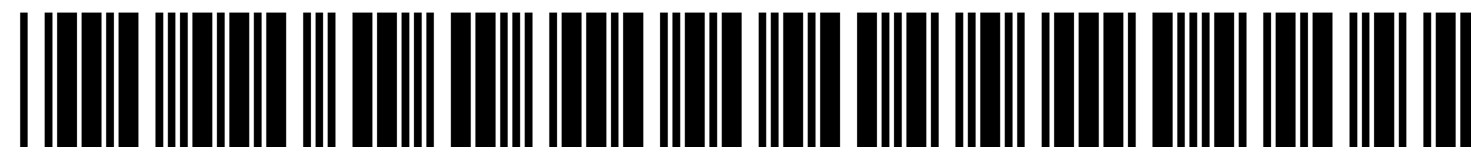
US007226175B2

(12) **United States Patent**
Matsumoto et al.

(10) **Patent No.: US 7,226,175 B2**
(45) **Date of Patent: *Jun. 5, 2007**

(54) **IMAGE EXPOSURE DEVICE AND LASER EXPOSURE DEVICE APPLIED THERETO**

(75) Inventors: **Kenji Matsumoto**, Kanagawa (JP); **Toshiro Hayakawa**, Kanagawa (JP); **Yoshinori Morimoto**, Kanagawa (JP); **Kiichi Kato**, Kanagawa (JP)

(73) Assignee: **Fujifilm Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/142,254**

(22) Filed: **Jun. 2, 2005**

(65) **Prior Publication Data**

US 2005/0218413 A1 Oct. 6, 2005

Related U.S. Application Data

(62) Division of application No. 10/329,762, filed on Dec. 27, 2002, now Pat. No. 6,977,780.

(30) **Foreign Application Priority Data**

Dec. 27, 2001	(JP)	....	2001-398416
Dec. 27, 2001	(JP)	....	2001-398442
Dec. 27, 2001	(JP)	....	2001-398443
Nov. 18, 2002	(JP)	....	2002-333938
Nov. 29, 2002	(JP)	....	2002-347742

(51) **Int. Cl.**
G02B 27/00 (2006.01)

(52) **U.S. Cl.** **359/601**; 359/566; 359/738; 372/50.11; 372/102

(58) **Field of Classification Search** 359/566, 359/601–608, 719, 738, 613, 614, 568, 569, 359/572, 573; 372/50.11, 102
See application file for complete search history.

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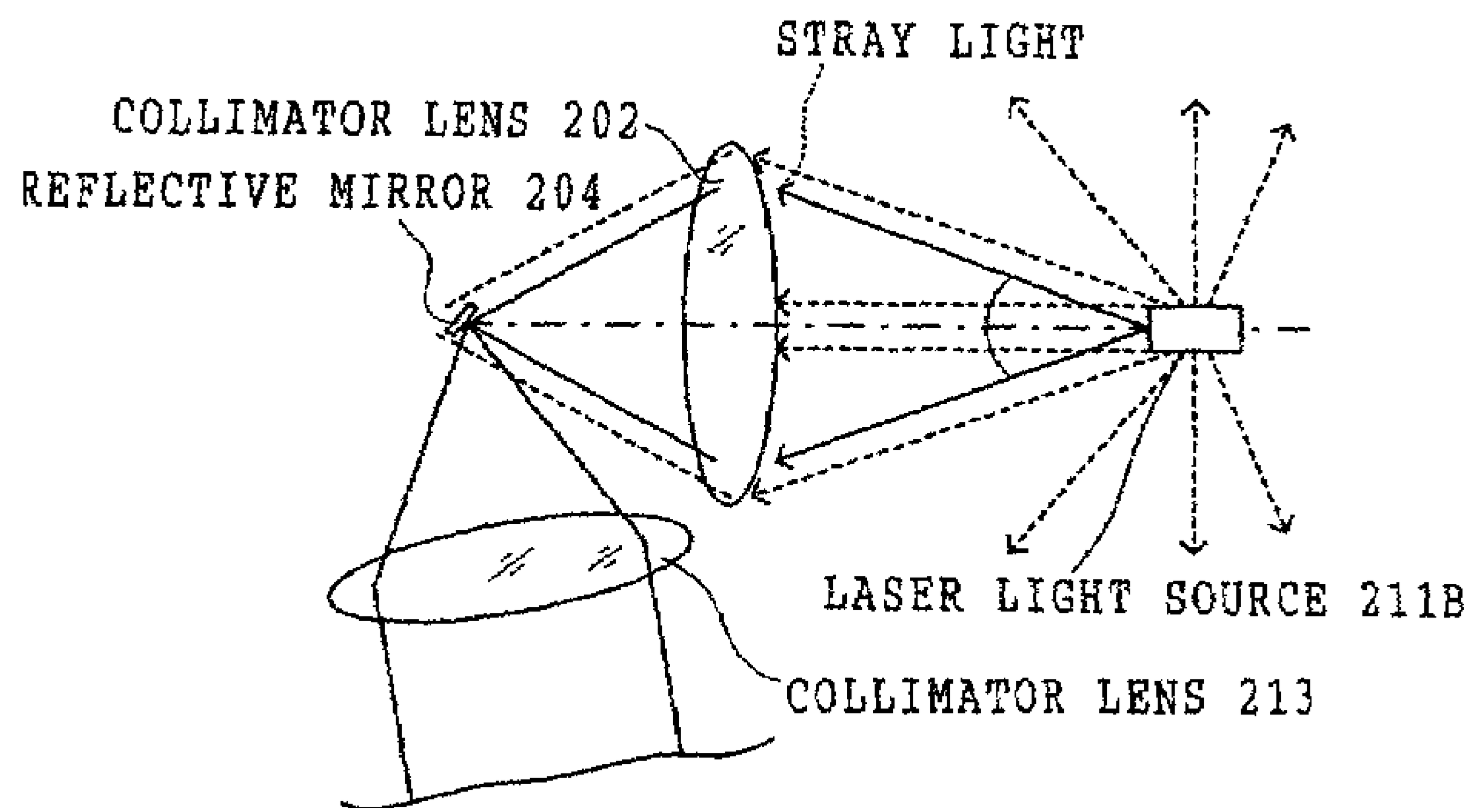
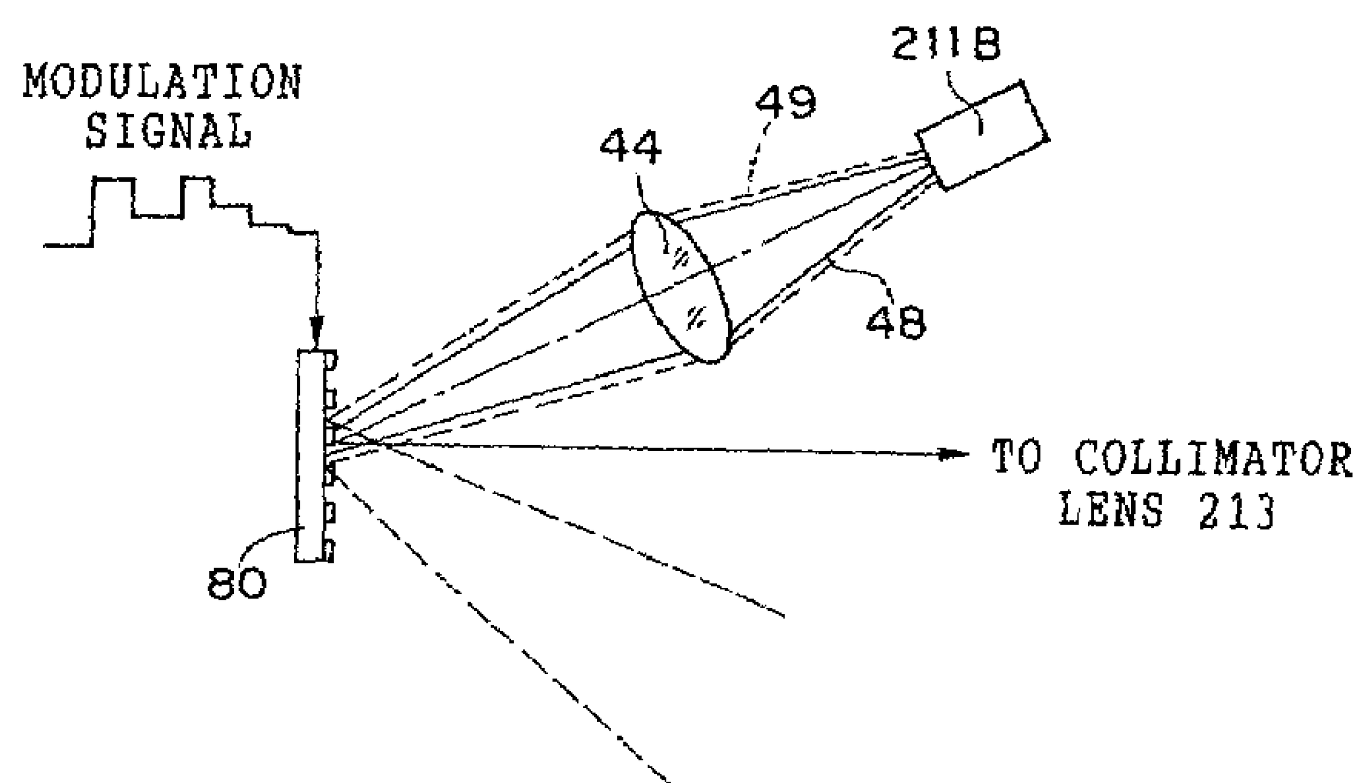
Primary Examiner—Hung Dang
Assistant Examiner—Joseph Martinez
(74) *Attorney, Agent, or Firm*—Sughrue Mion, PLLC

(57) **ABSTRACT**

When a ratio R between a total angle ϕ of a widening angle in a median intensity of light of a light source (a GaN based semiconductor laser) and a total angle 2/ϕ of a widening angle of light defining a numerical aperture NA of a collimator optical system (collimator lens) is defined as $R=(\sin^{-1}NA)\times 2/\phi$, the numerical aperture of the collimator optical system (collimator lens) is set so that $2.0 \geqq R \geqq 0.58$. Thus, an image exposure device is provided that can suppress stray light of a light source that emits a large amount of stray light.

16 Claims, 30 Drawing Sheets





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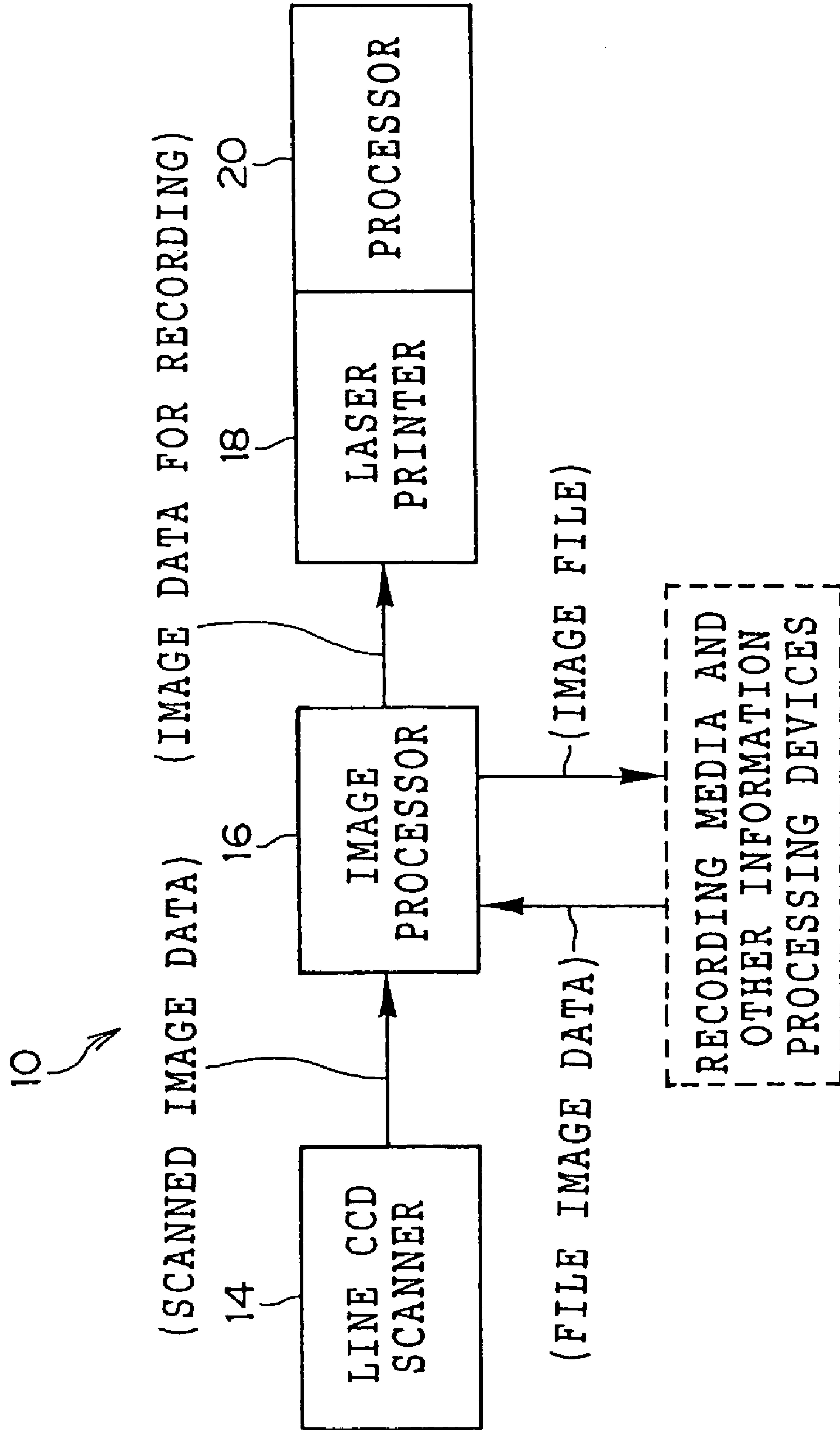


FIG.1
10
14
LINE CCD SCANNER
(SCANNED IMAGE DATA)
16
IMAGE PROCESSOR
(IMAGE DATA FOR RECORDING)
18
LASER PRINTER
20
PROCESSOR
(IMAGE FILE)
(FILE IMAGE DATA)
RECORDING MEDIA AND OTHER INFORMATION PROCESSING DEVICES

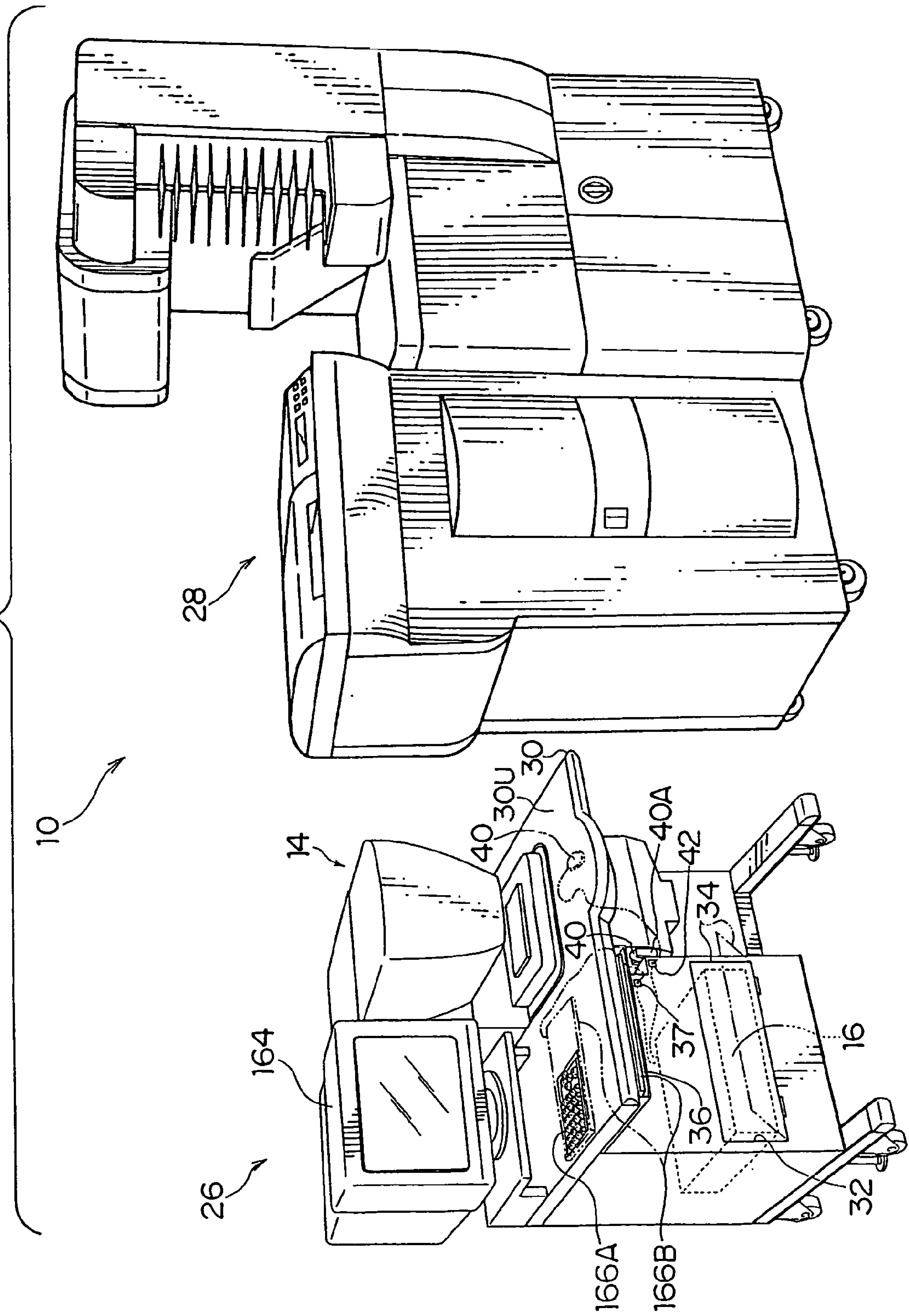


FIG.2
10
28
14
26
164
30
30U
40
40A
42
34
37
16
36
32
166A
166B

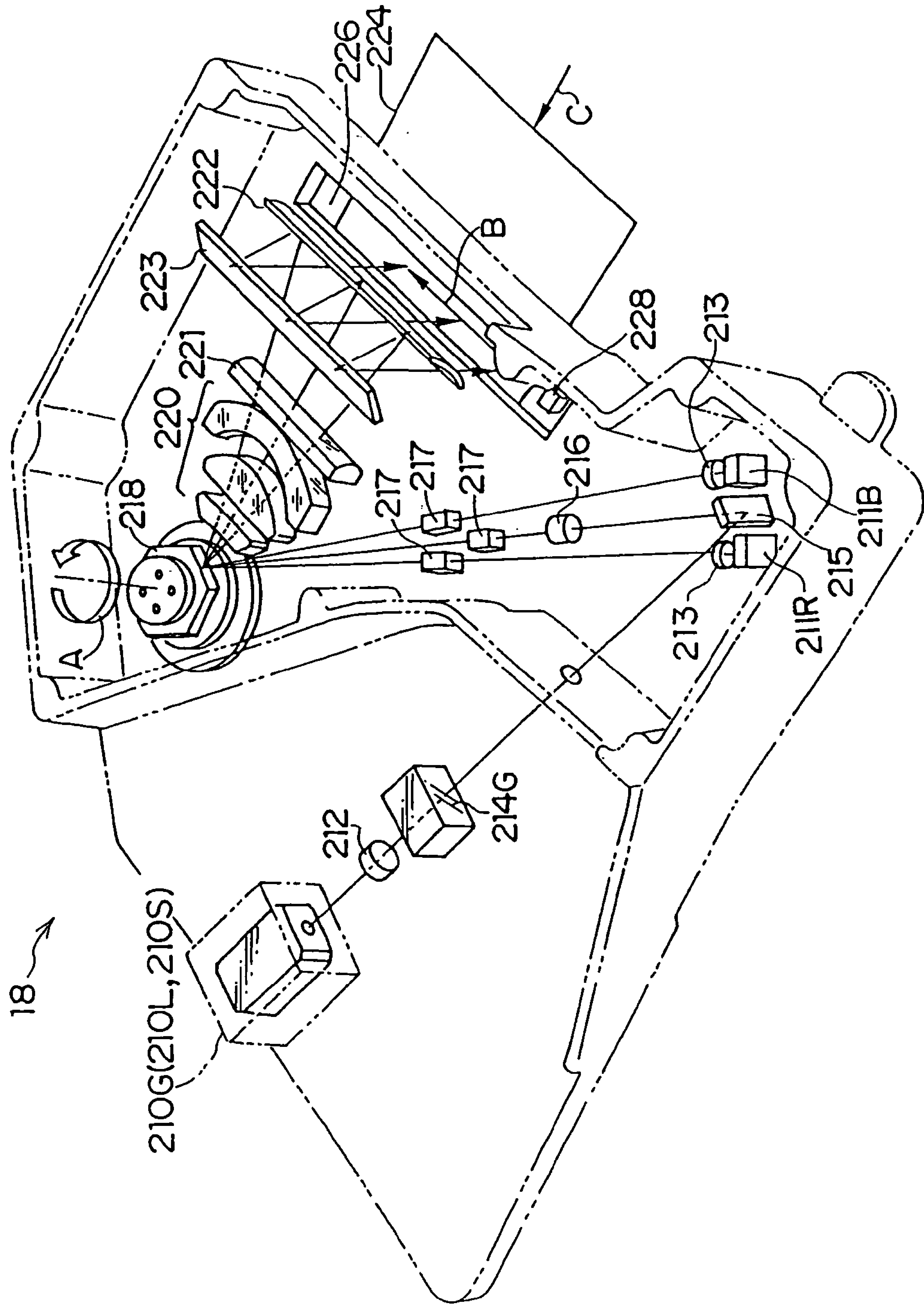
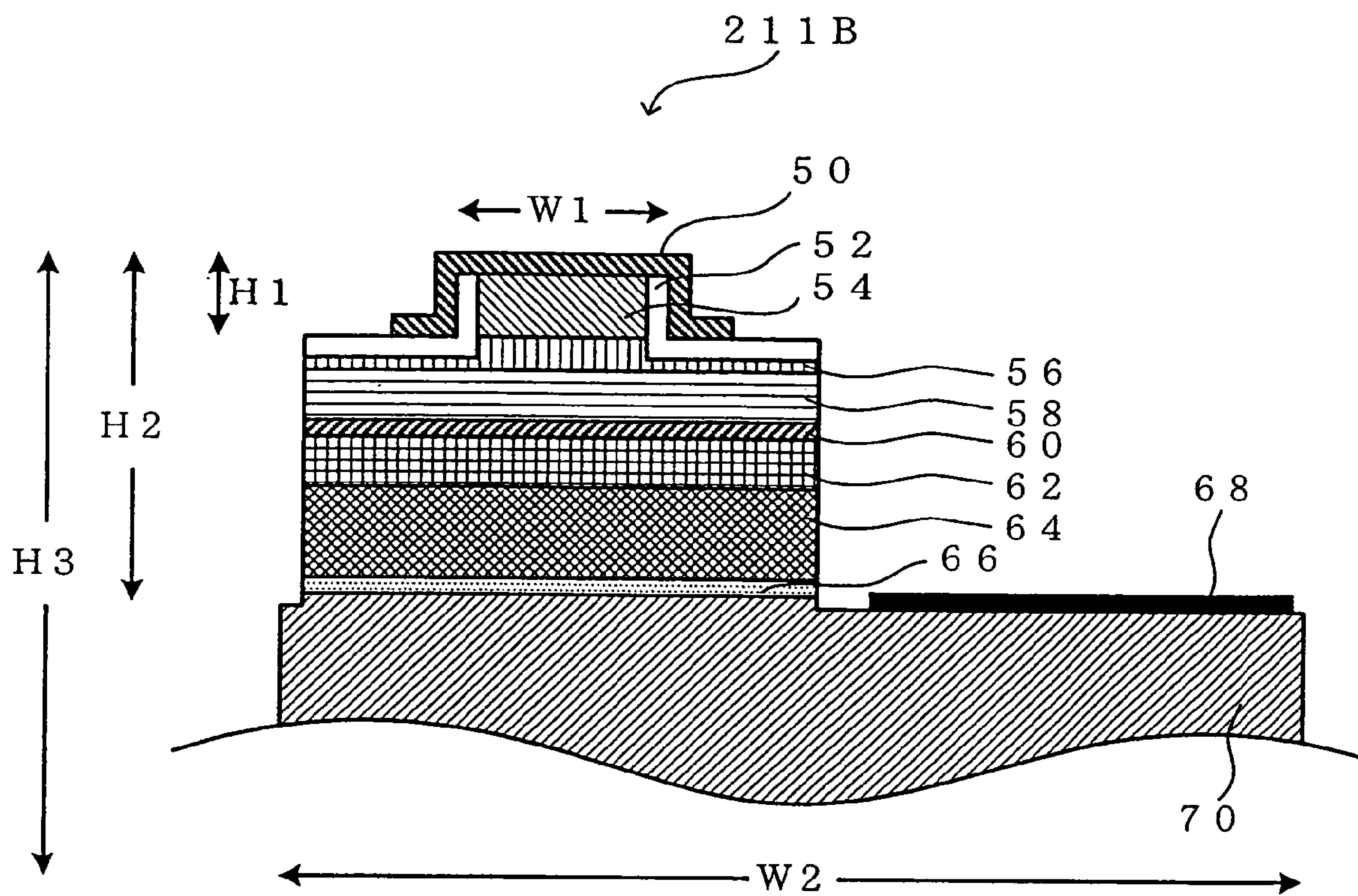


FIG.3
18
210G(210L,210S)
212
214G
213
211R
215
211B
213
216
217
217
217
218
A
220
221
223
222
B
226
224
C
228

FIG.4



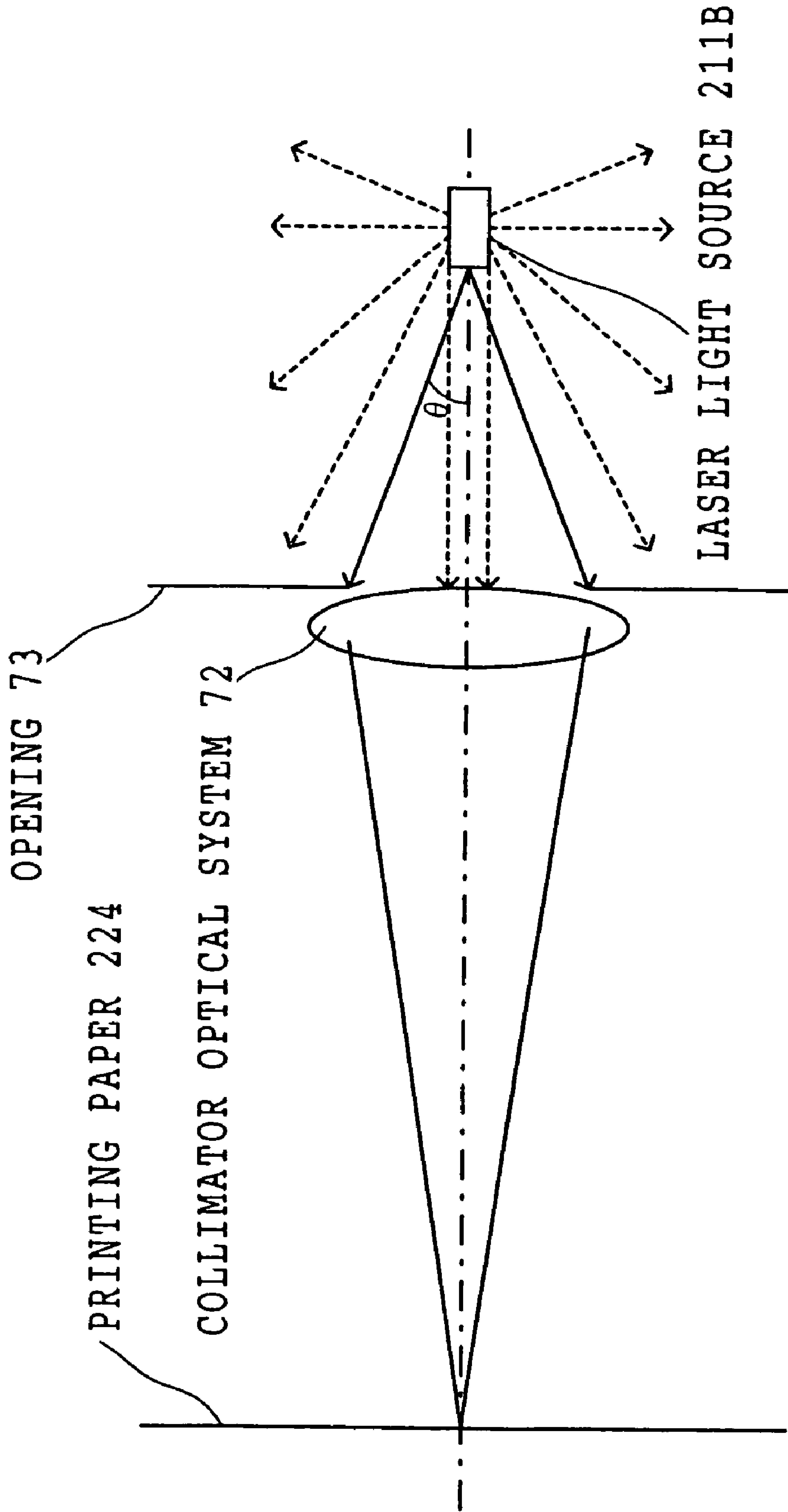


FIG.5
LASER LIGHT SOURCE 211B
θ
OPENING 73
COLLIMATOR OPTICAL SYSTEM 72
PRINTING PAPER 224

FIG.6A

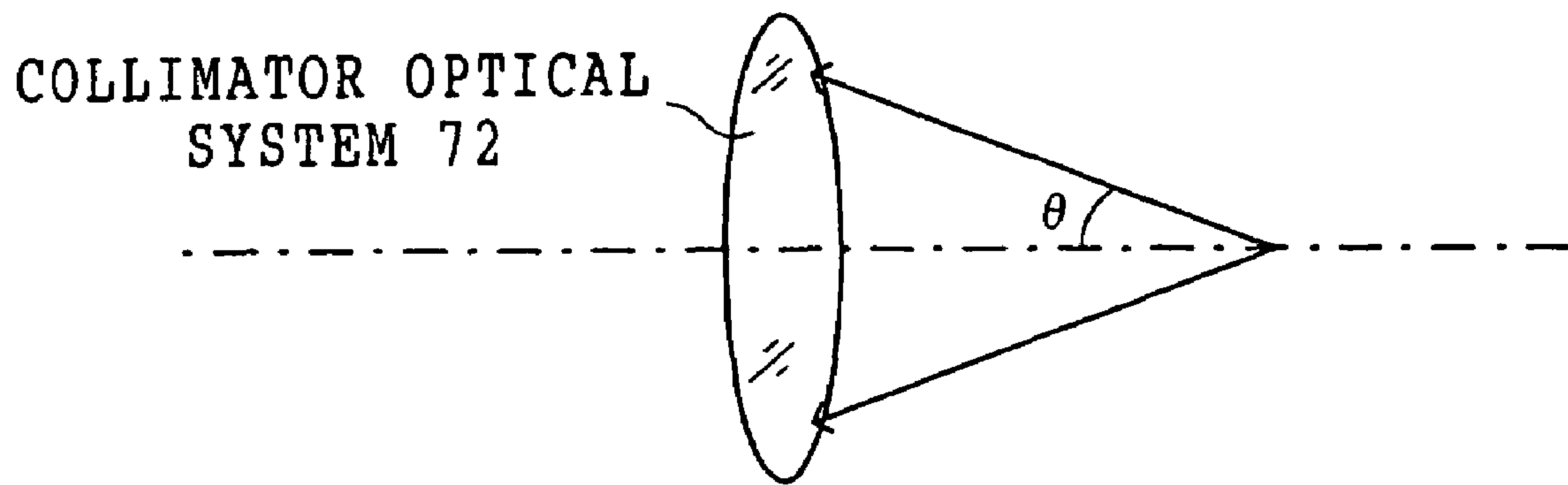


FIG.6B

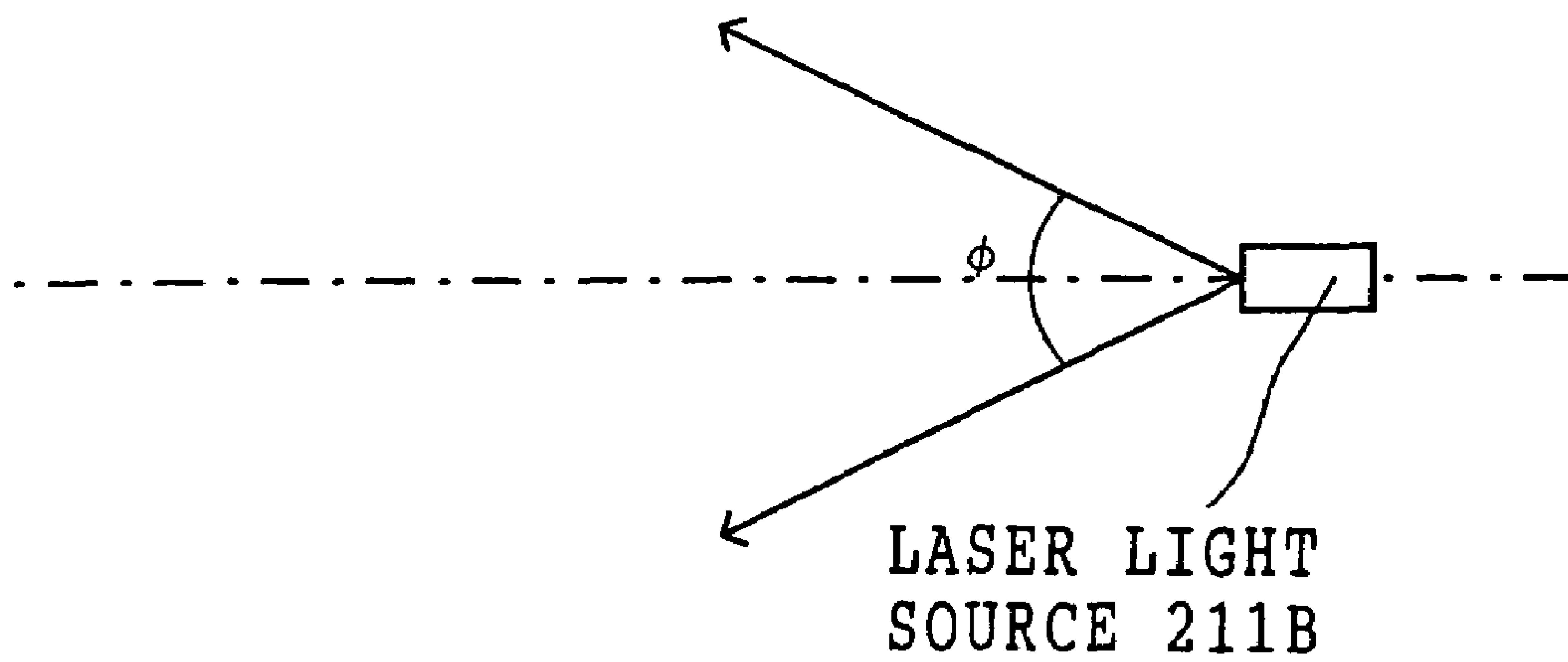


FIG.7

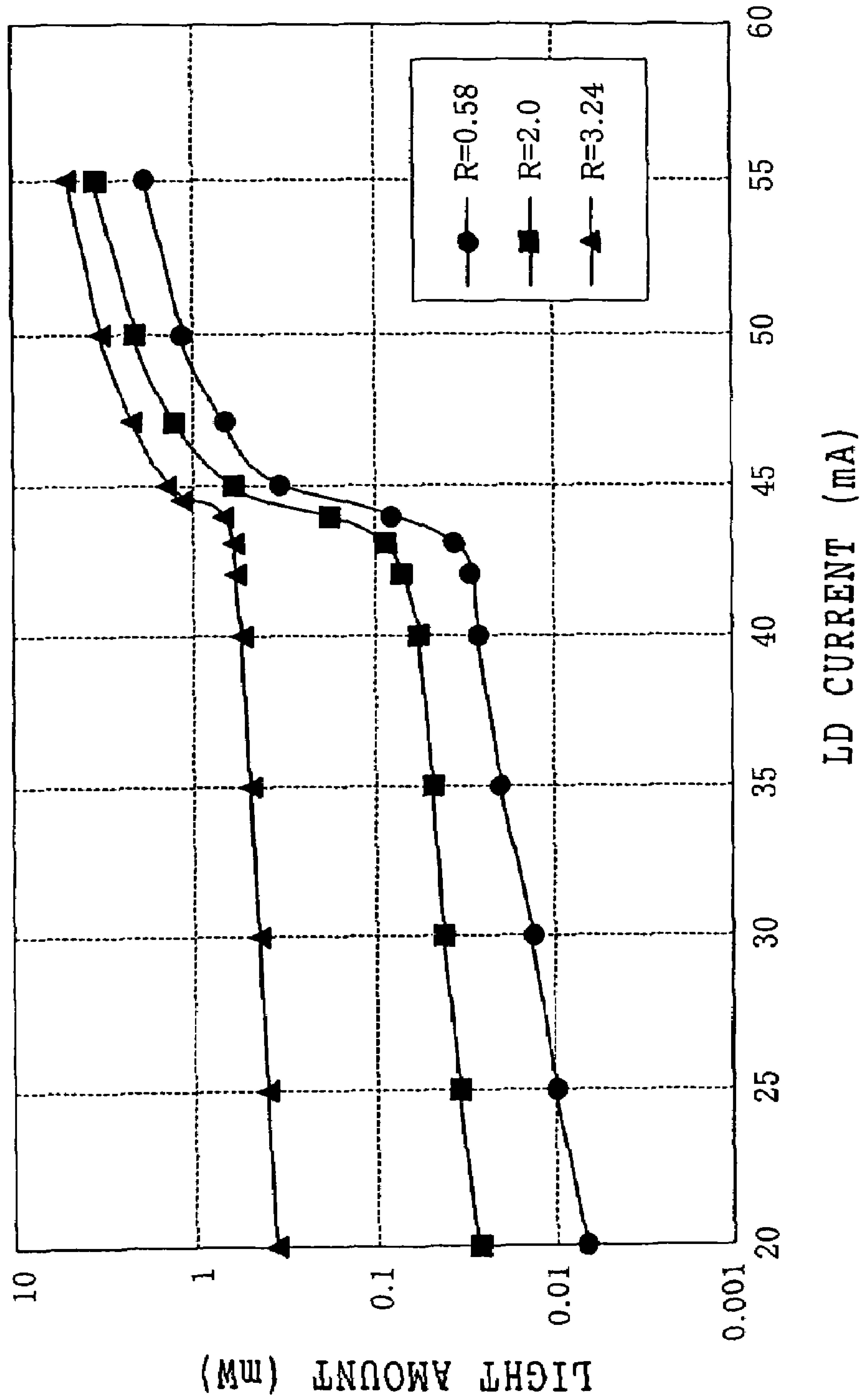


FIG.8A

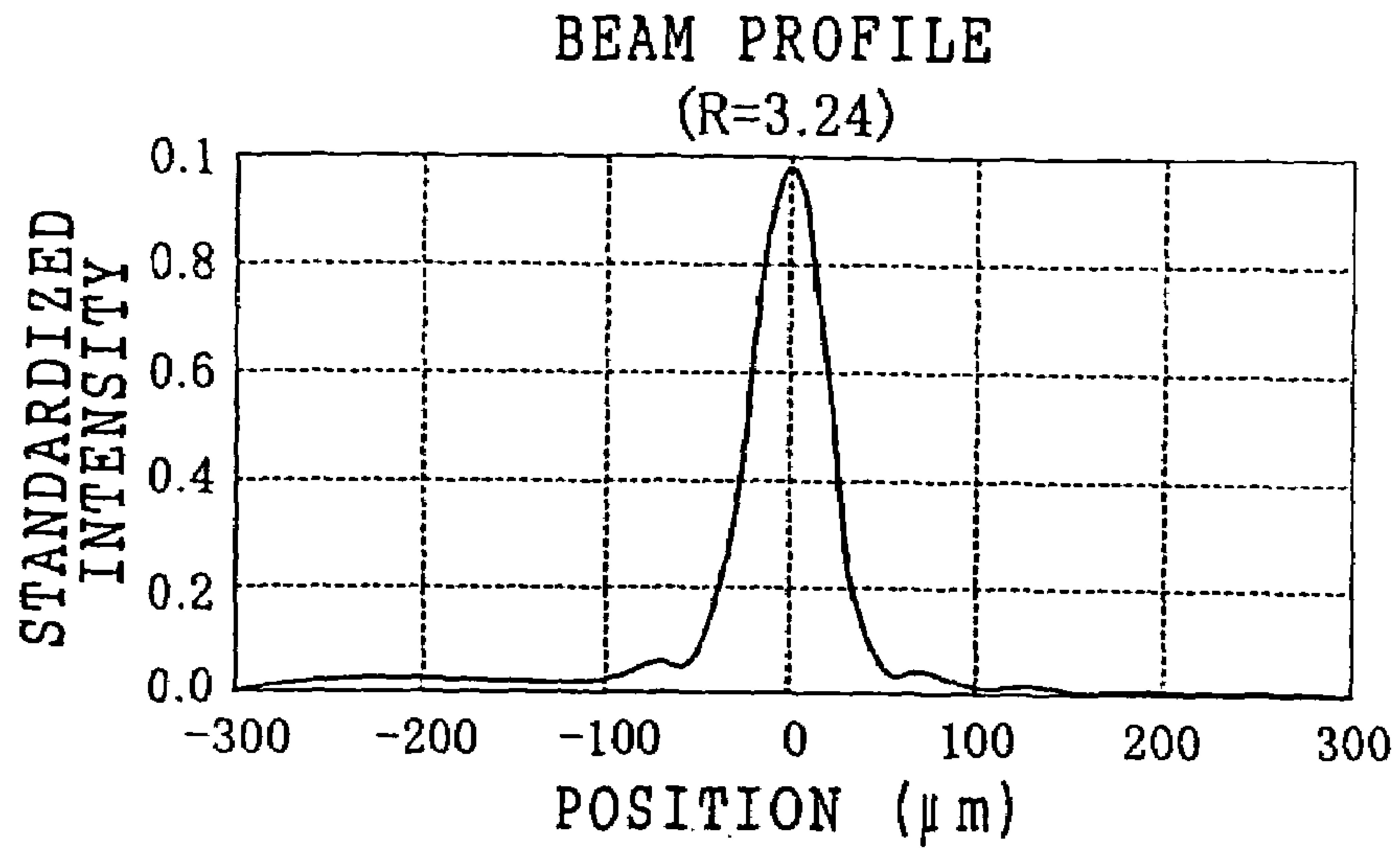


FIG.8B

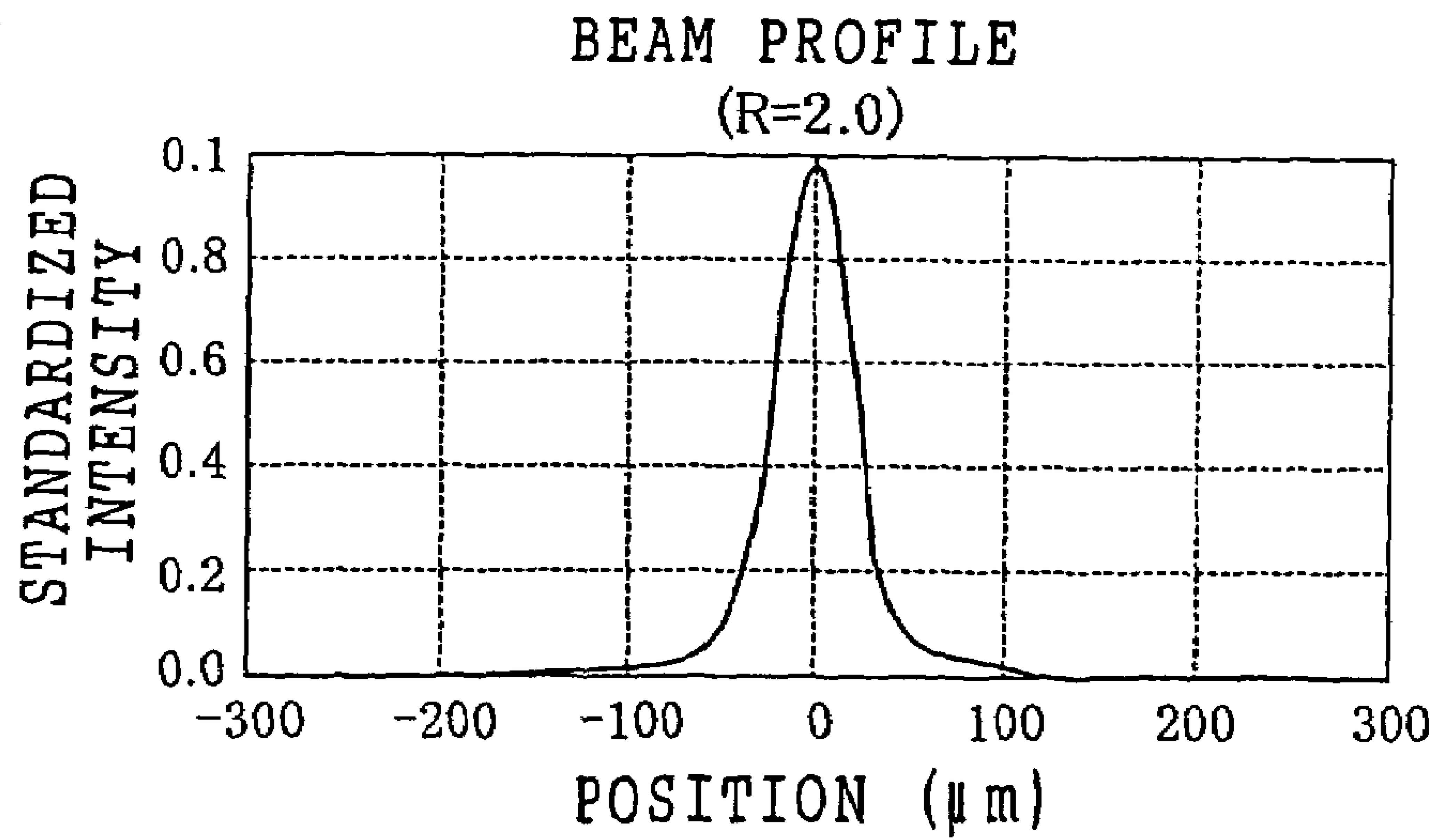


FIG.8C

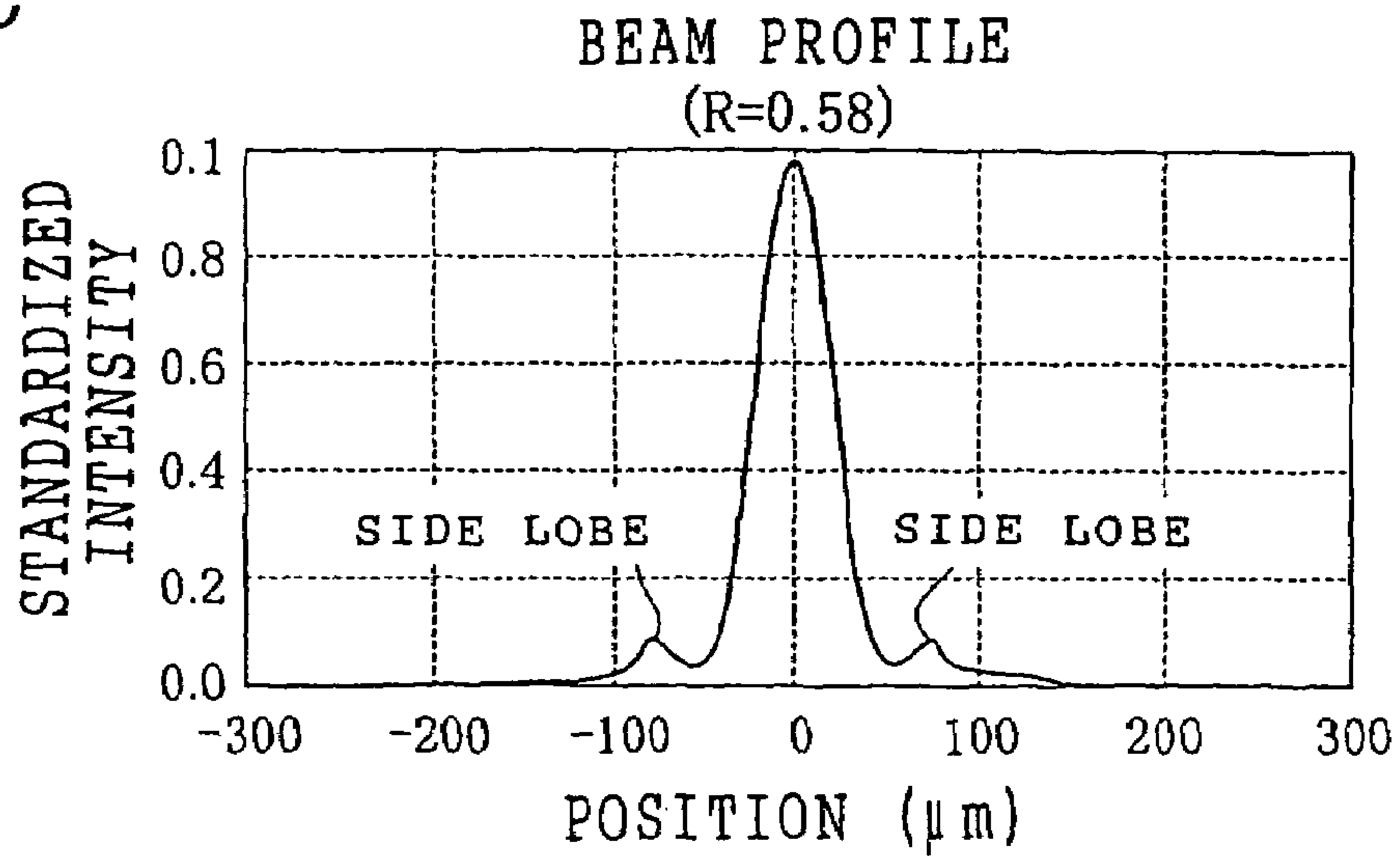
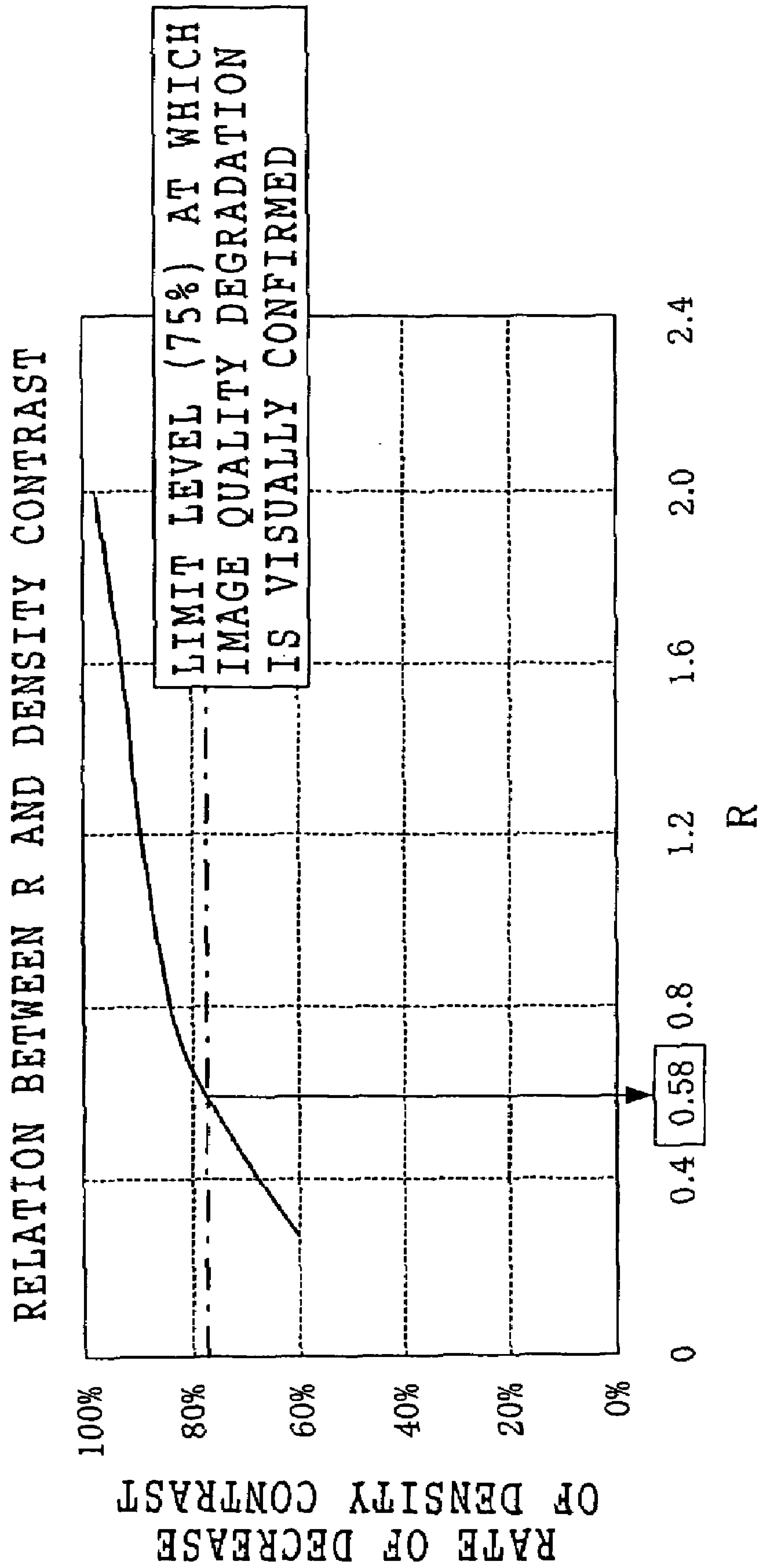


FIG.9



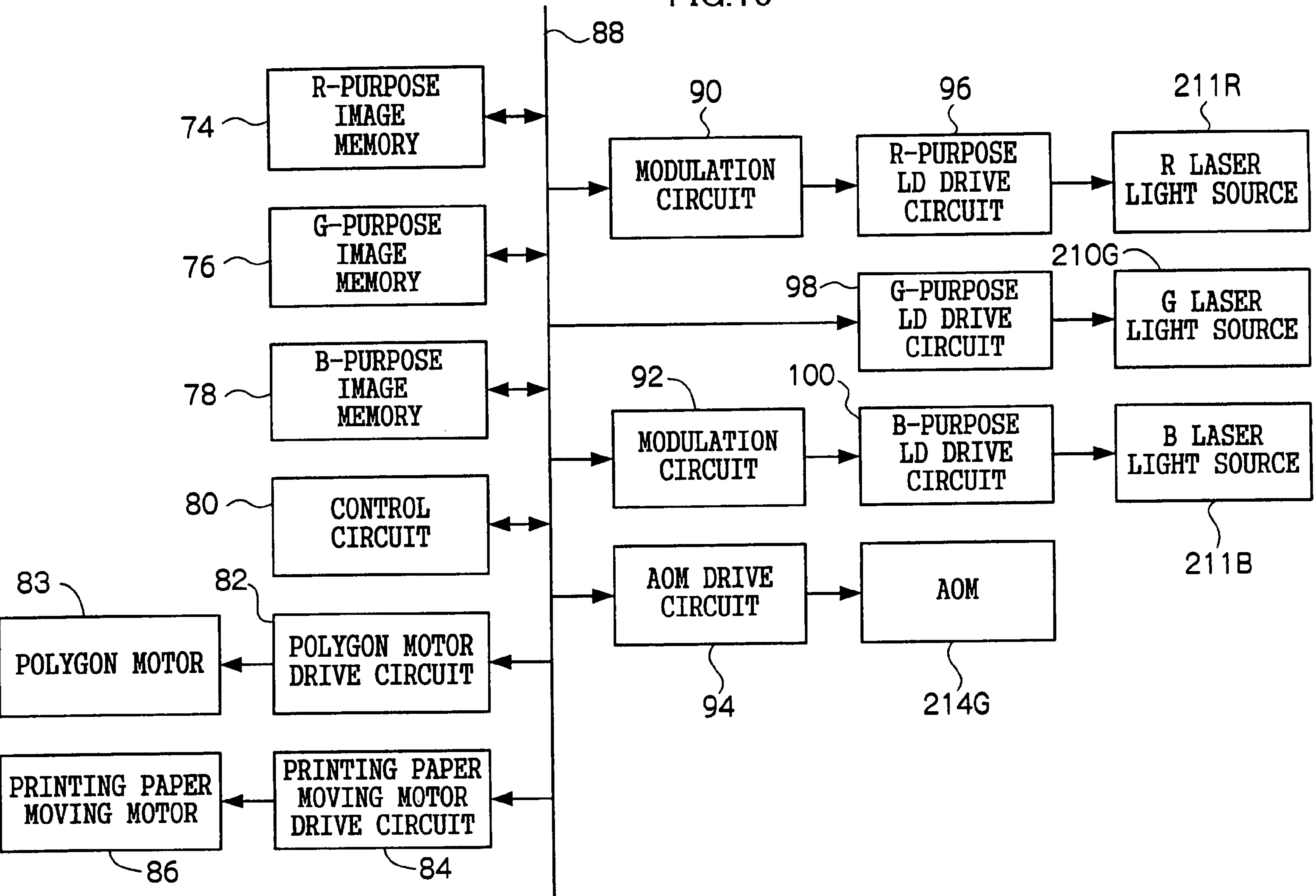


FIG.10
88
R-PURPOSE IMAGE MEMORY
74
G-PURPOSE IMAGE MEMORY
76
B-PURPOSE IMAGE MEMORY
78
CONTROL CIRCUIT
80
POLYGON MOTOR DRIVE CIRCUIT
82
POLYGON MOTOR
83
PRINTING PAPER MOVING MOTOR DRIVE CIRCUIT
84
PRINTING PAPER MOVING MOTOR
86
MODULATION CIRCUIT
90
MODULATION CIRCUIT
92
AOM DRIVE CIRCUIT
94
R-PURPOSE LD DRIVE CIRCUIT
96
G-PURPOSE LD DRIVE CIRCUIT
98
B-PURPOSE LD DRIVE CIRCUIT
100
AOM
214G
R LASER LIGHT SOURCE
211R
G LASER LIGHT SOURCE
210G
B LASER LIGHT SOURCE
211B

FIG.11

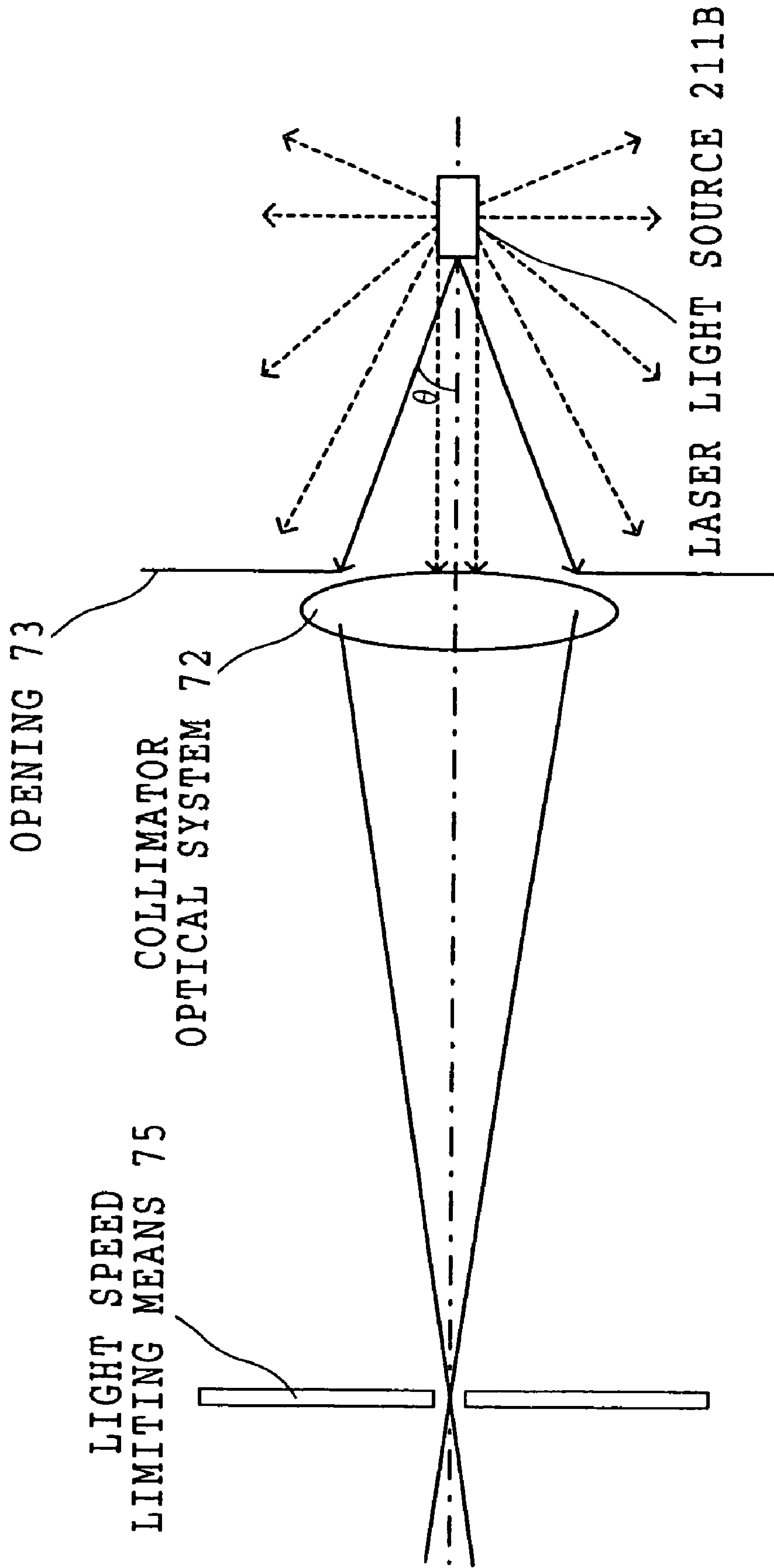


FIG.12

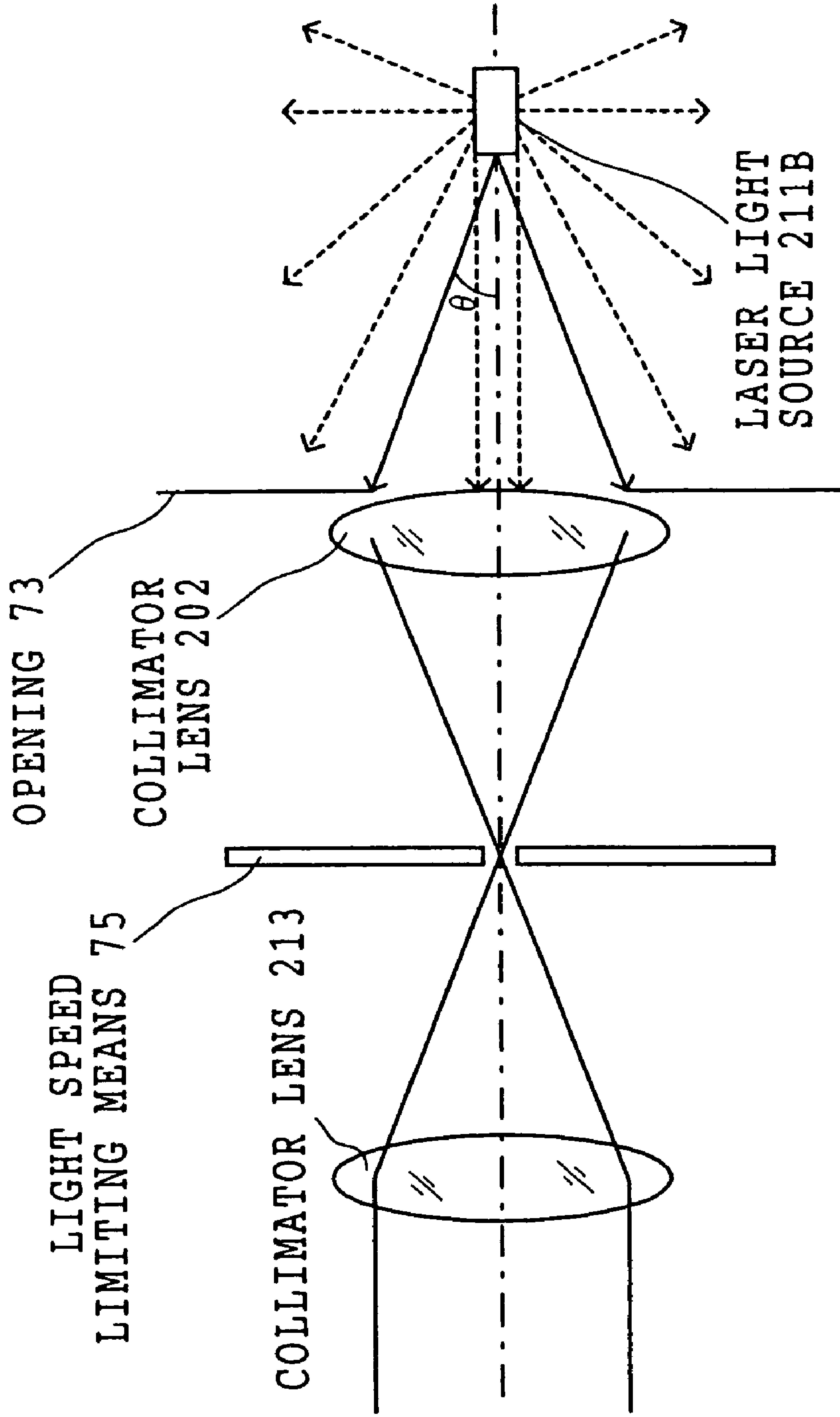


FIG.13

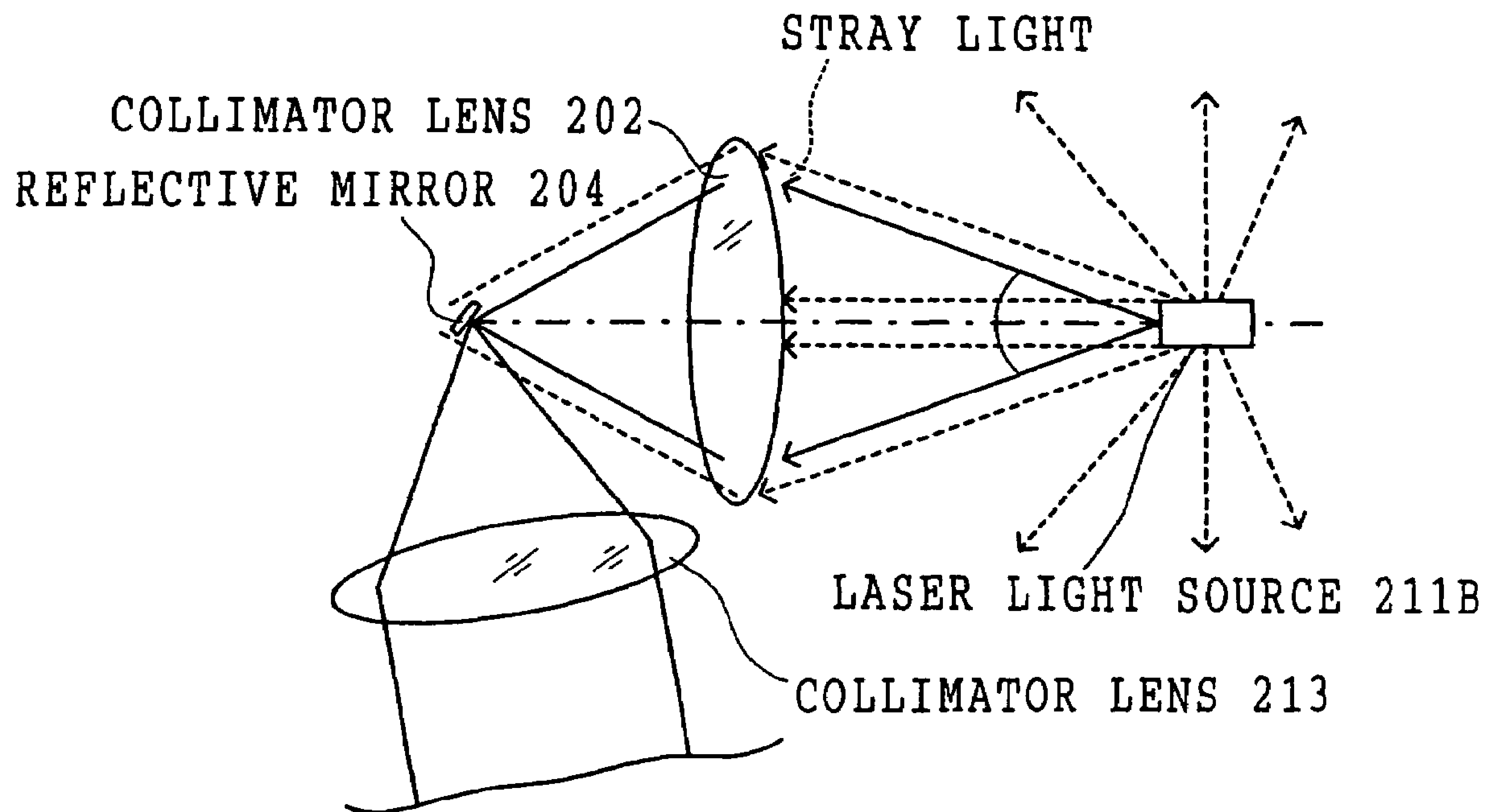


FIG.14

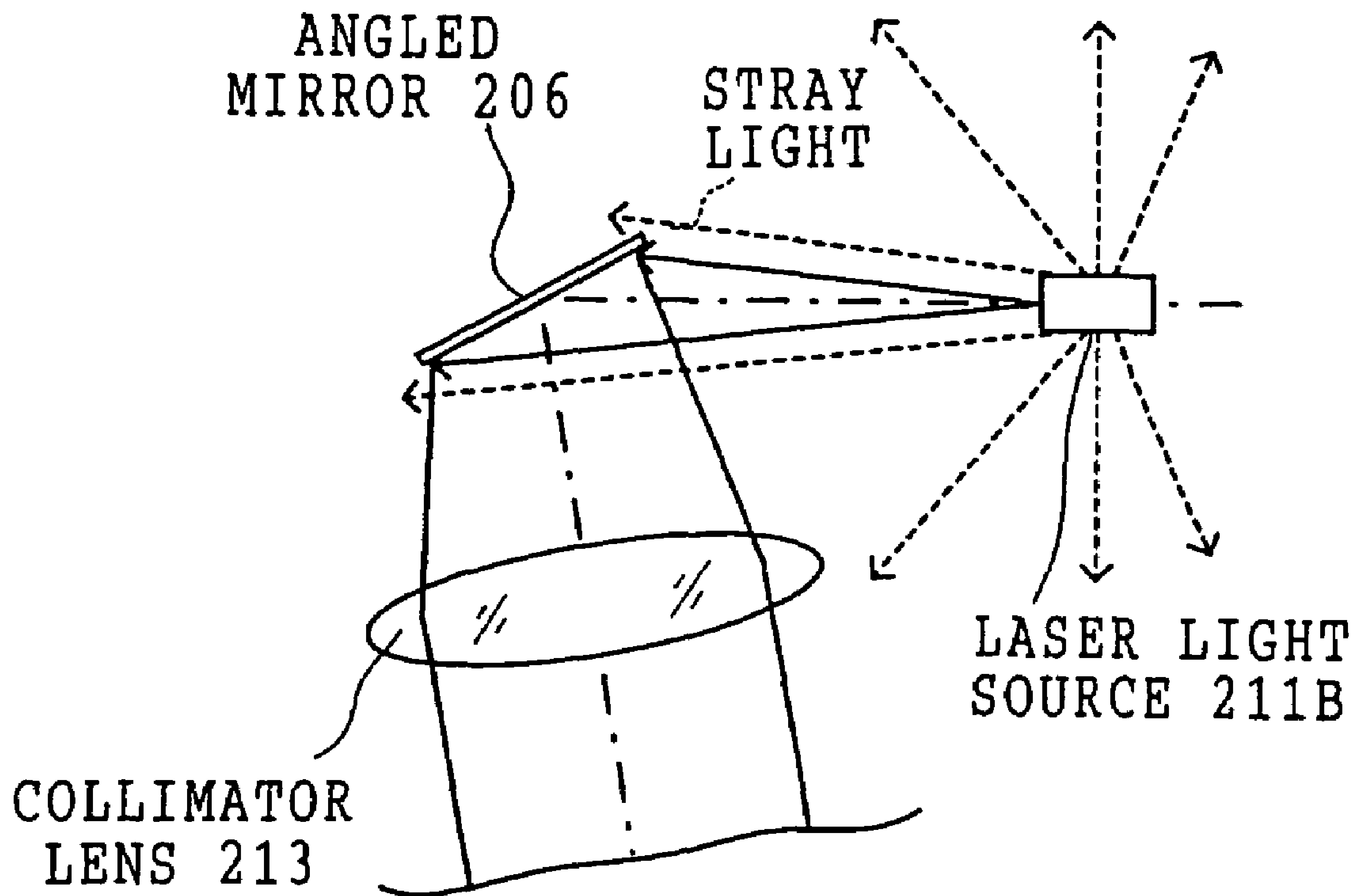


FIG.15

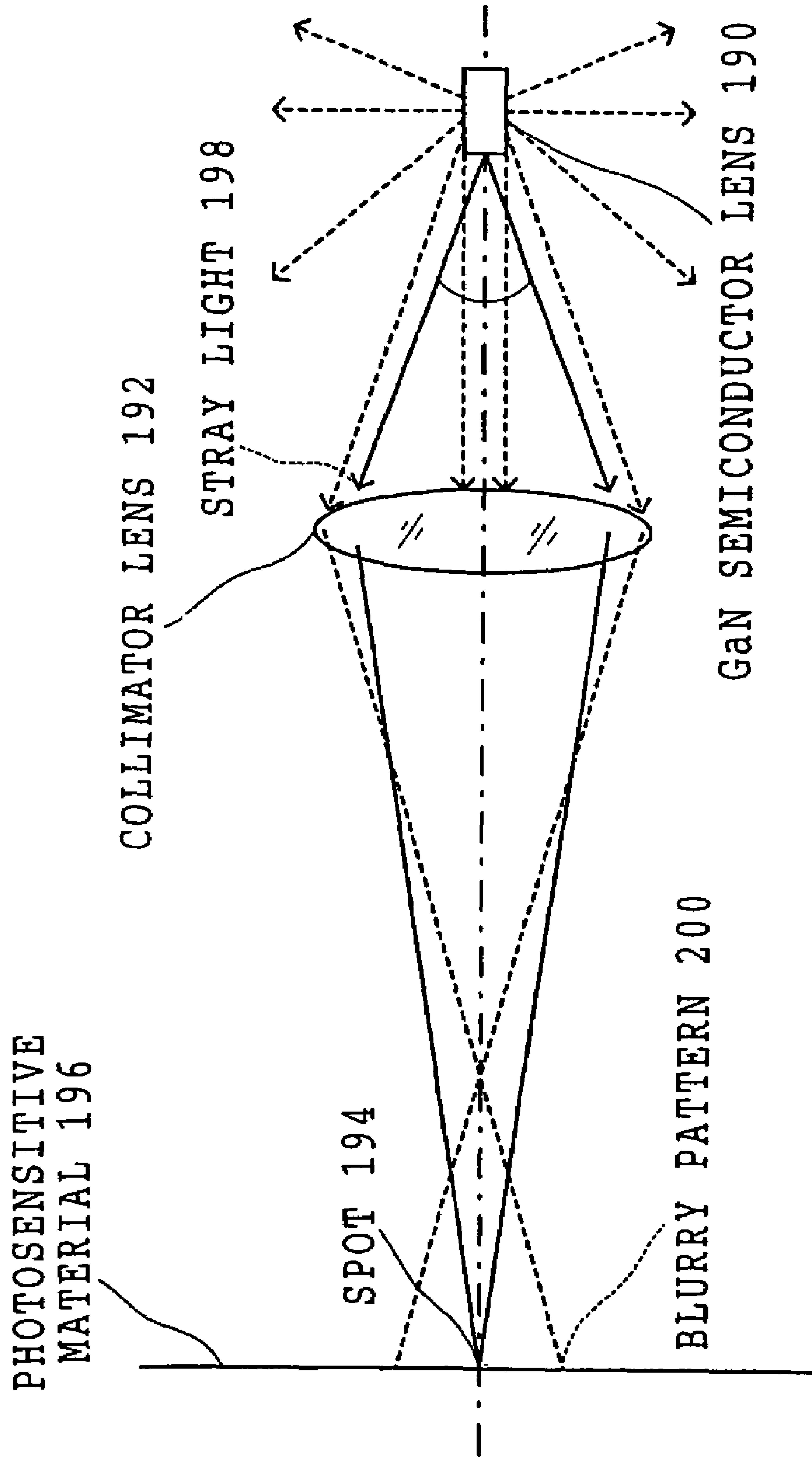


FIG.16

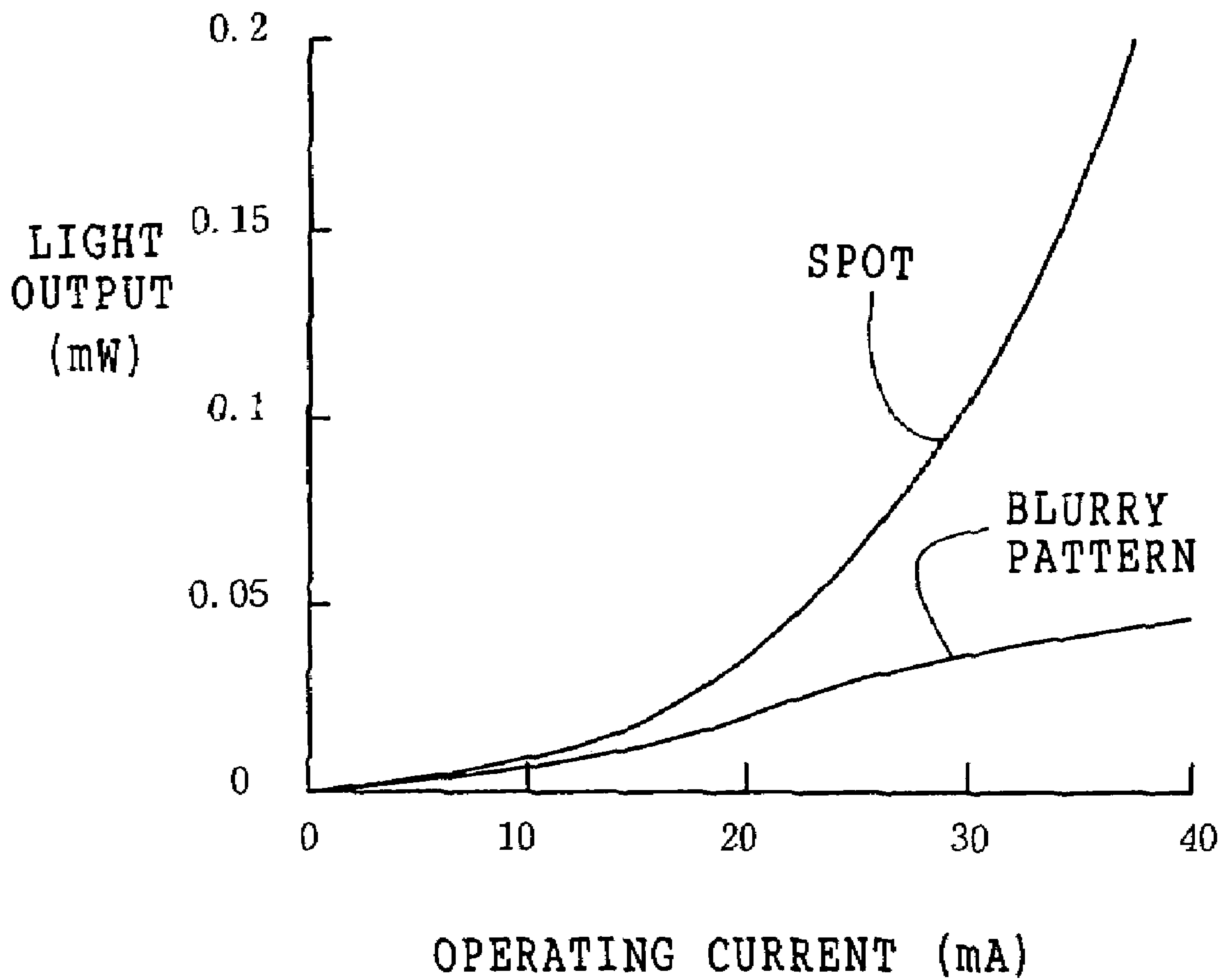


FIG.17A

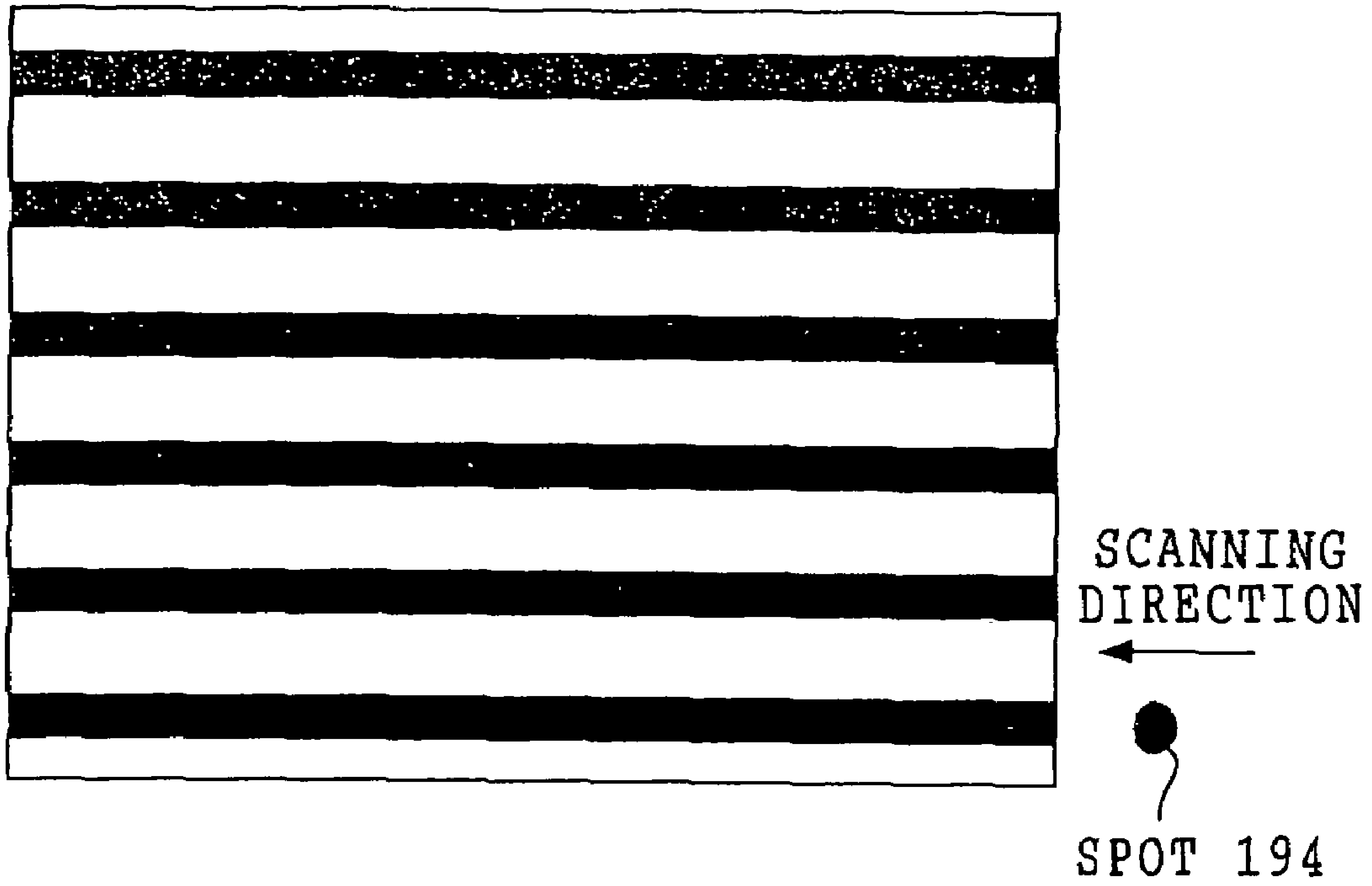
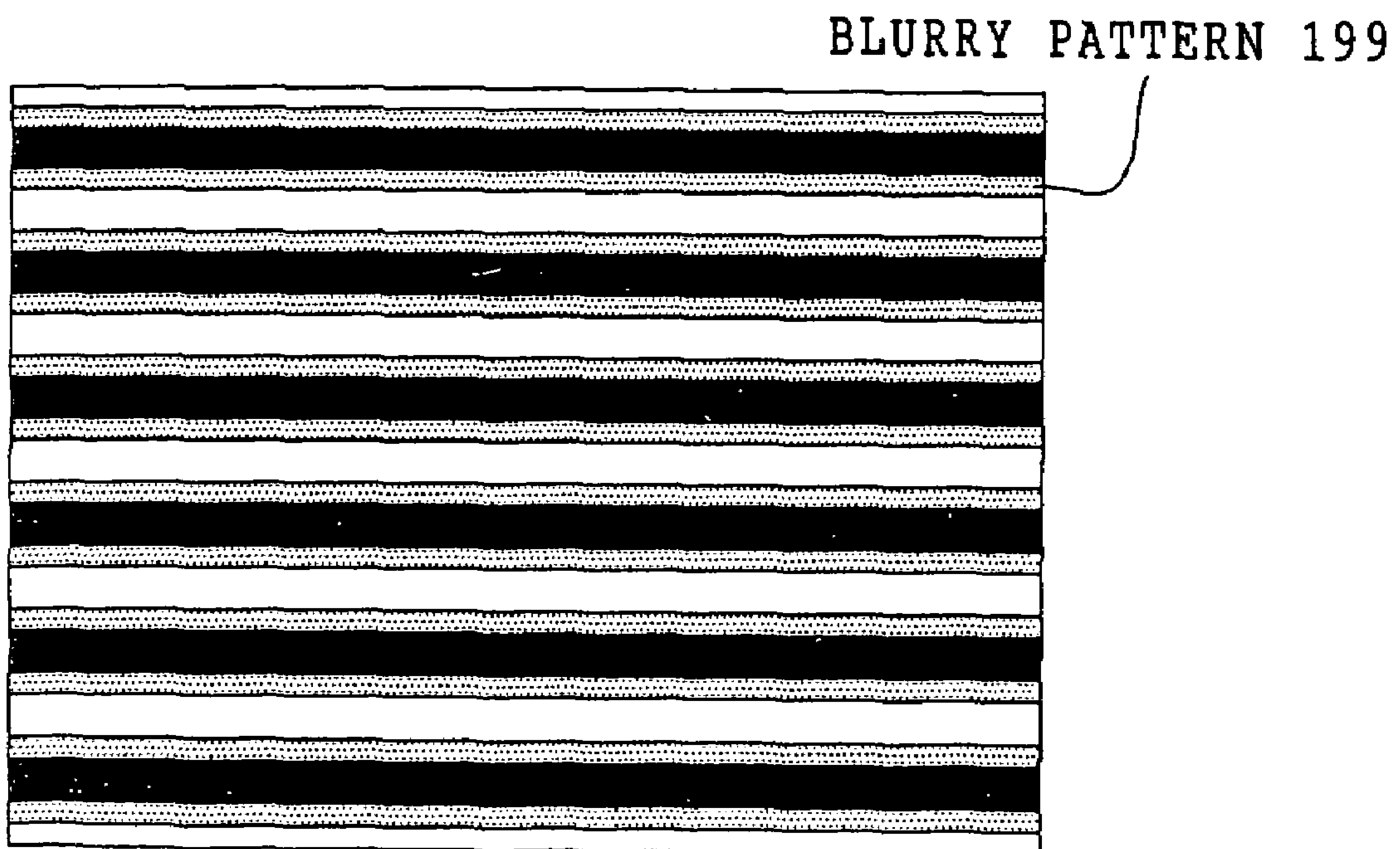


FIG.17B



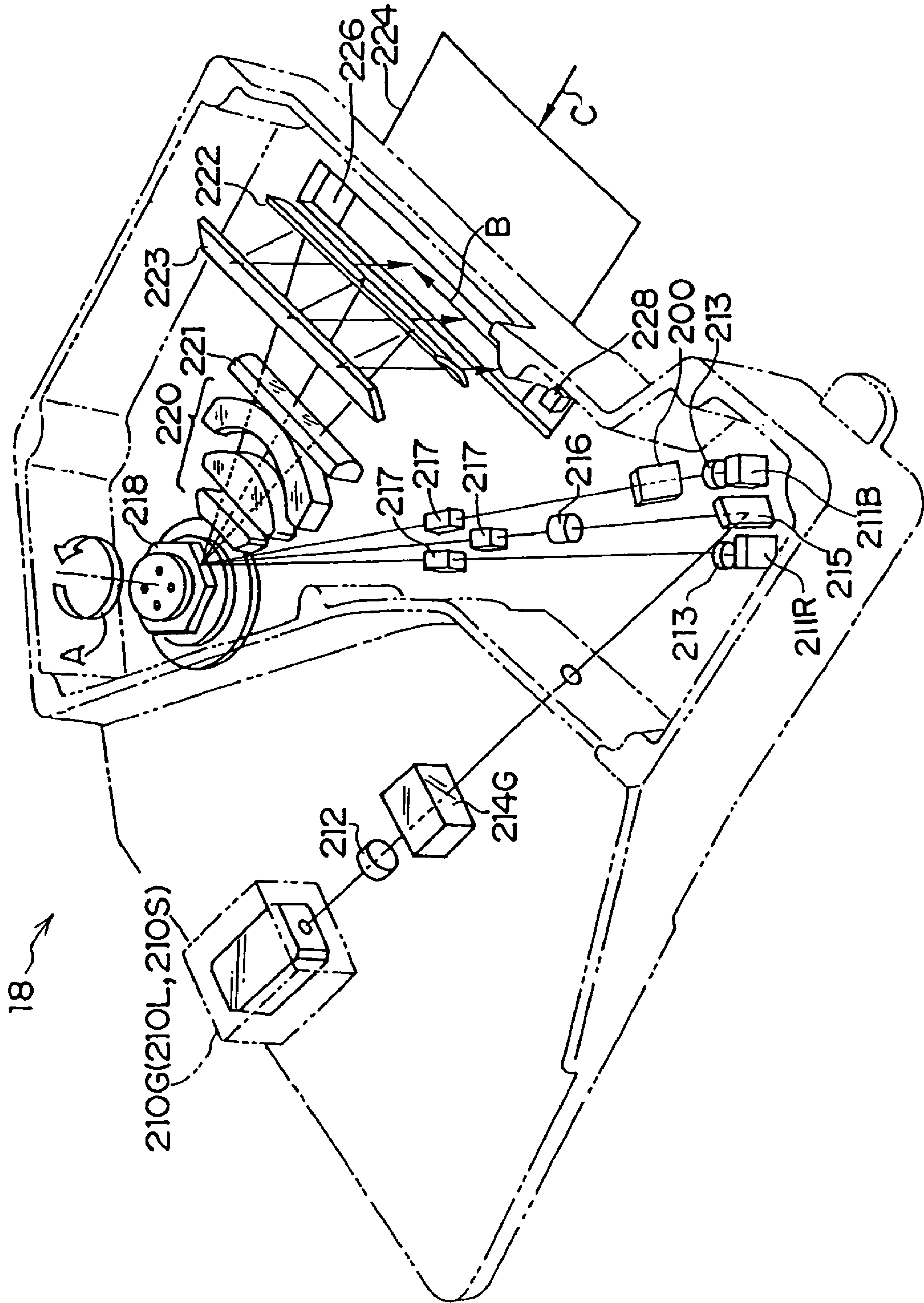
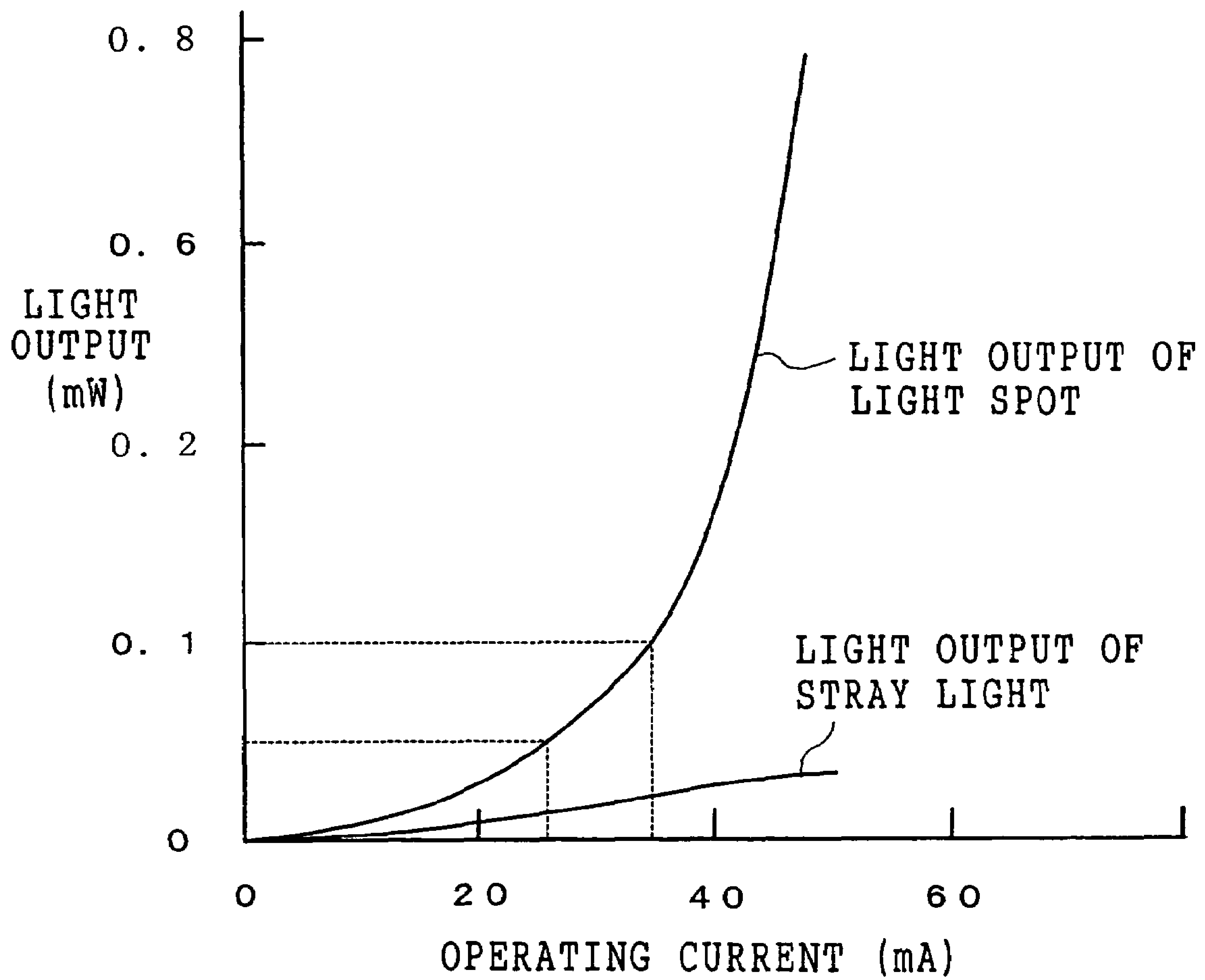


FIG.18

FIG.19



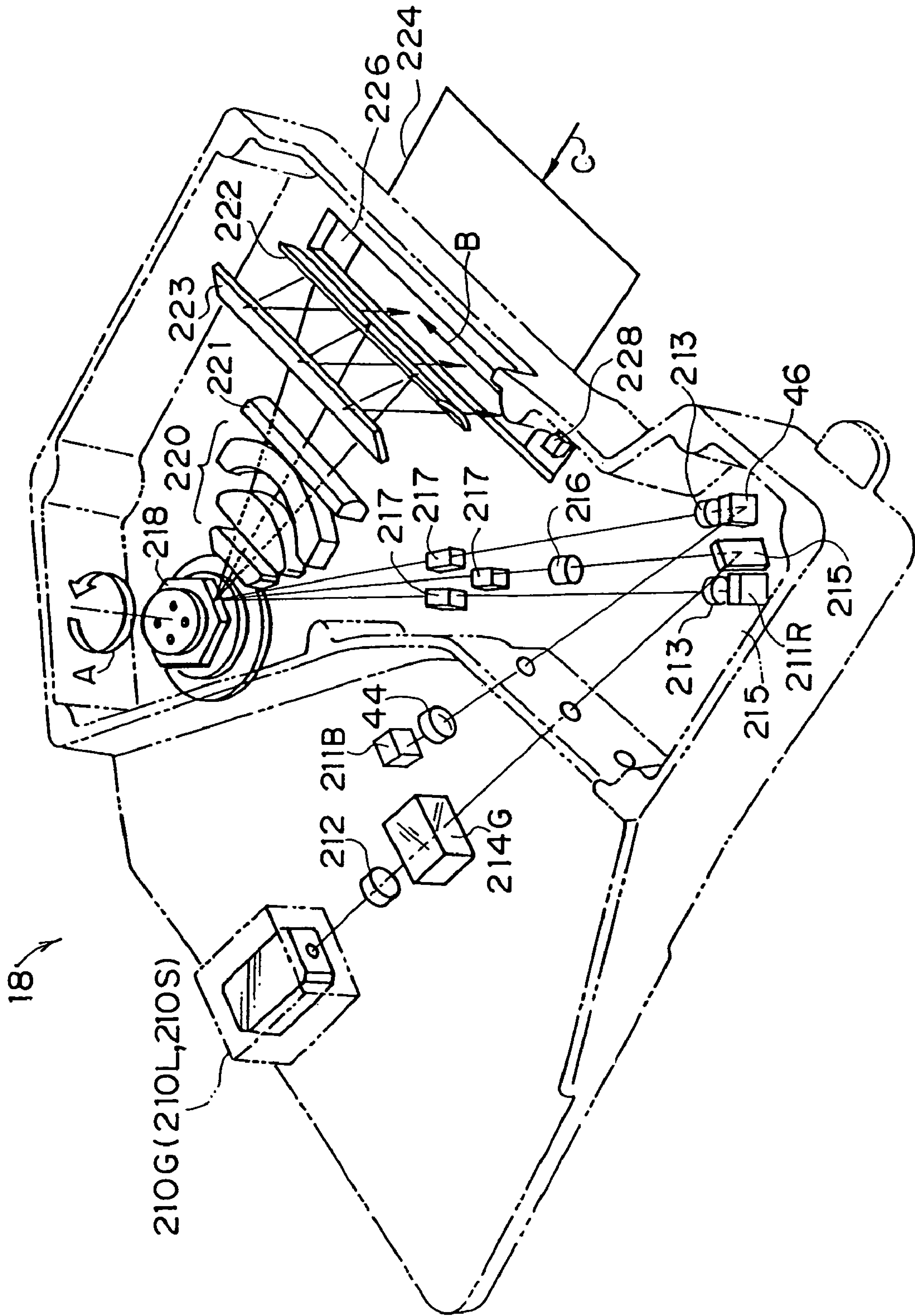


FIG.20
18
210G(210L,210S)
212
214G
211B
44
218
A
220
221
223
222
226
224
C
B
228
213
46
217
217
217
216
215
215
211R
213

FIG.21

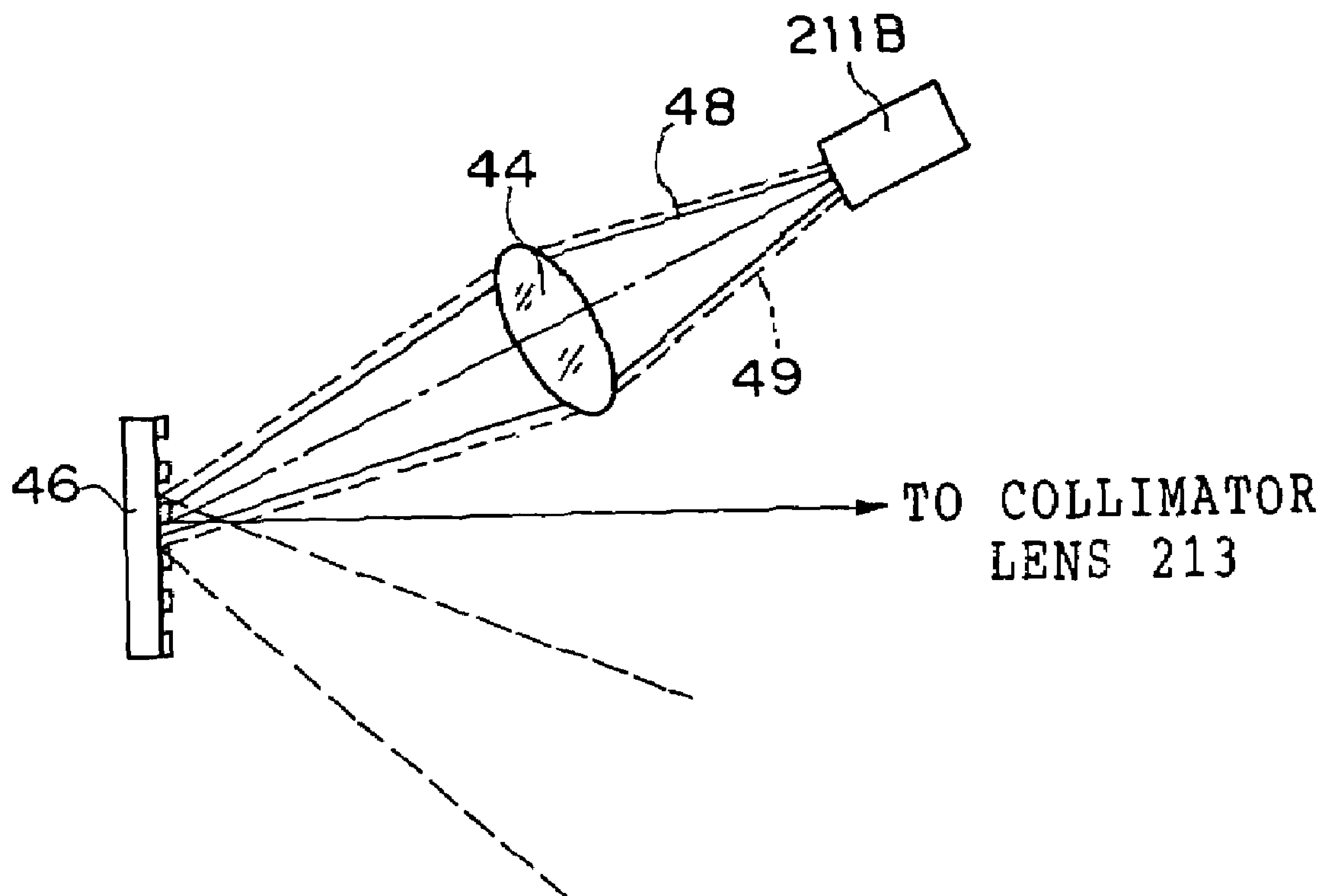


FIG.22

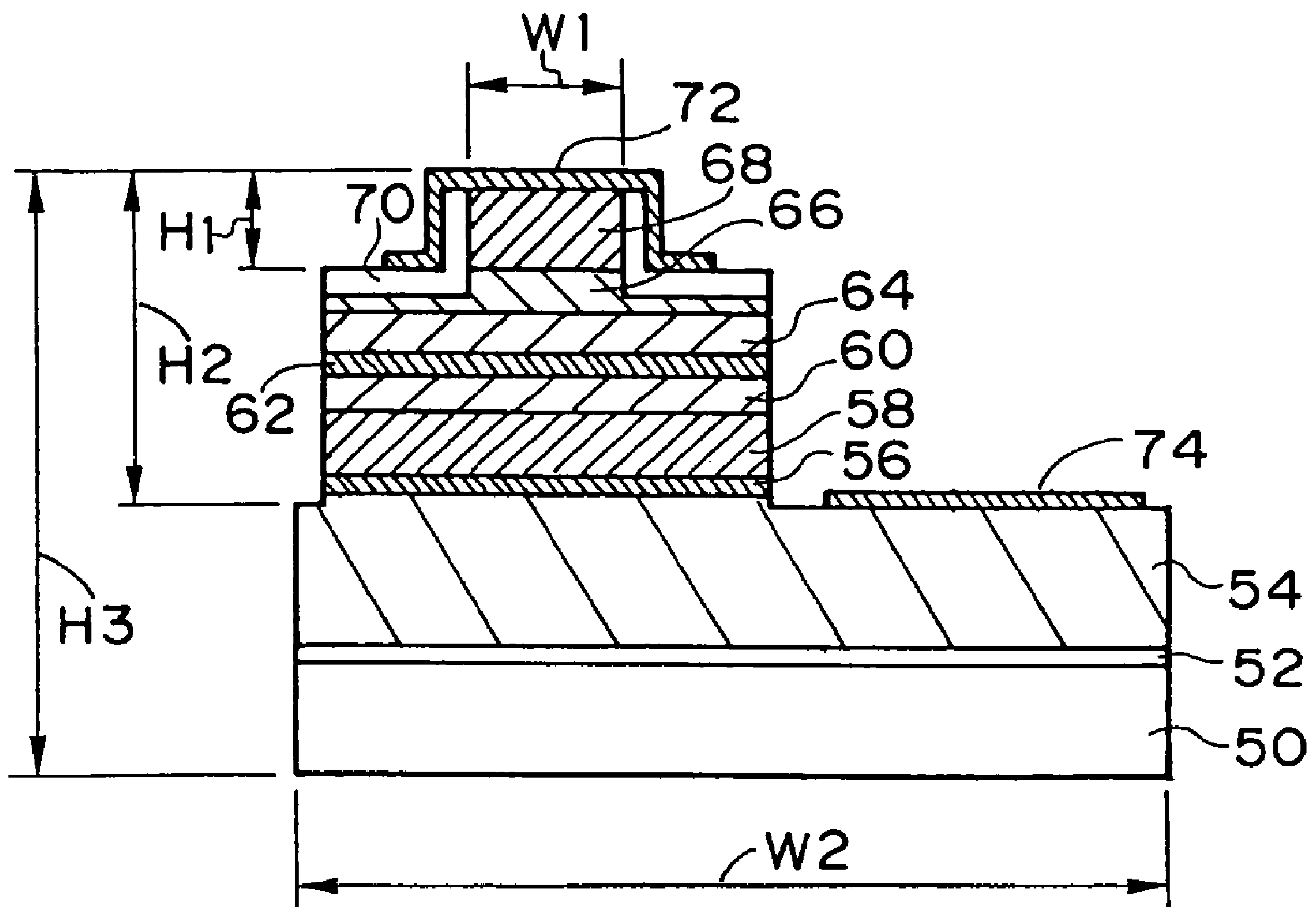


FIG.23

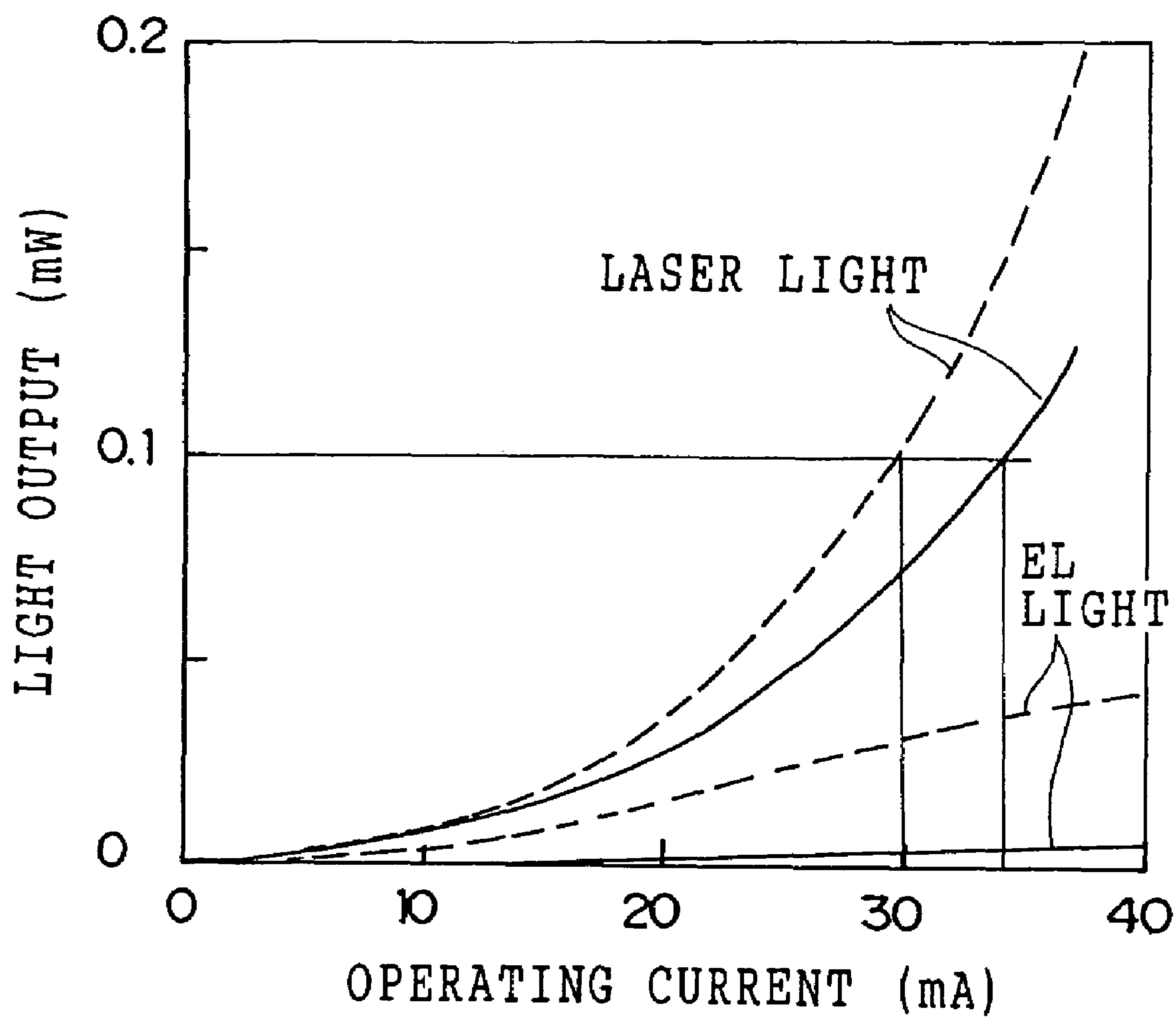


FIG.24

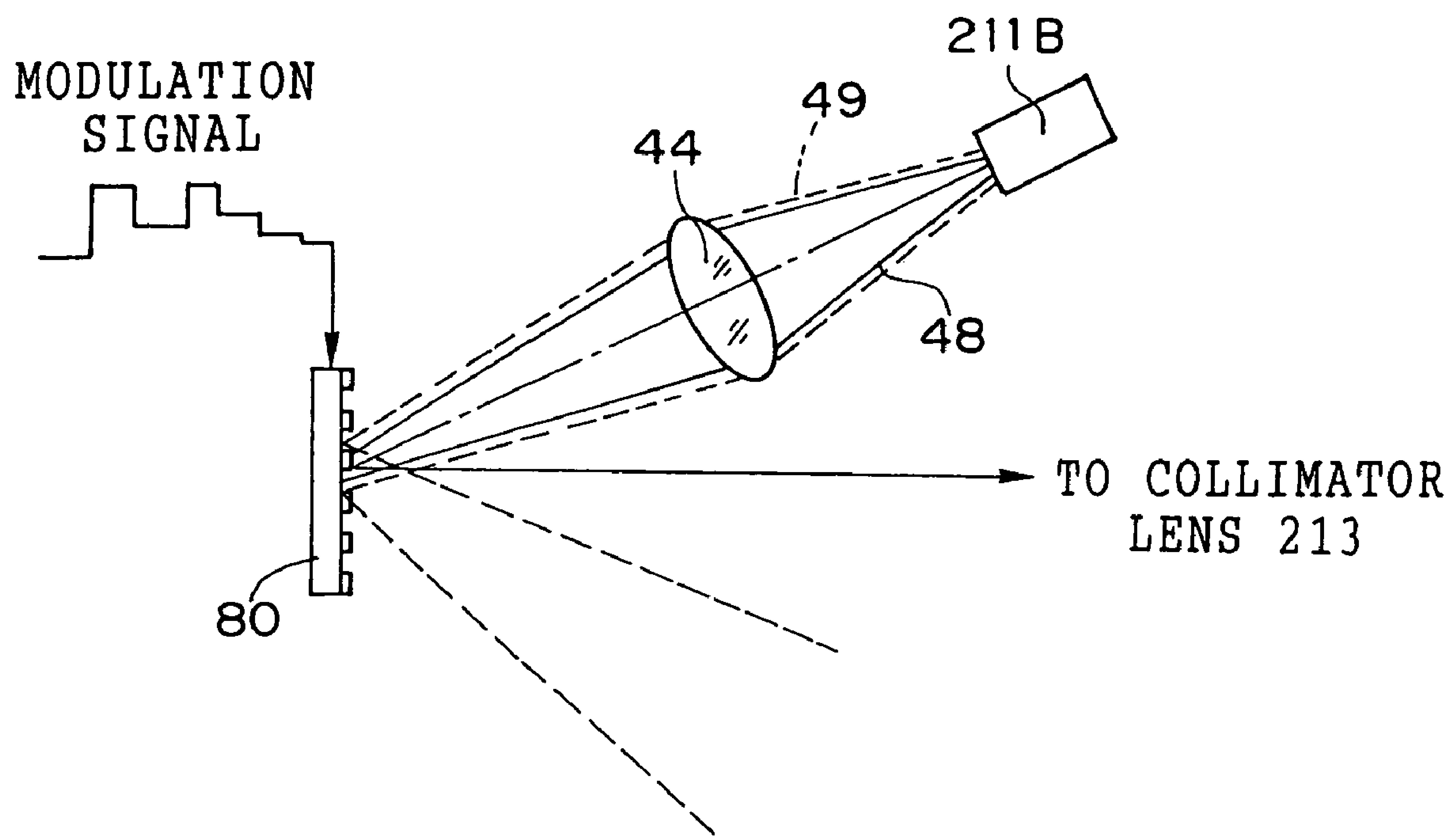


FIG.25A

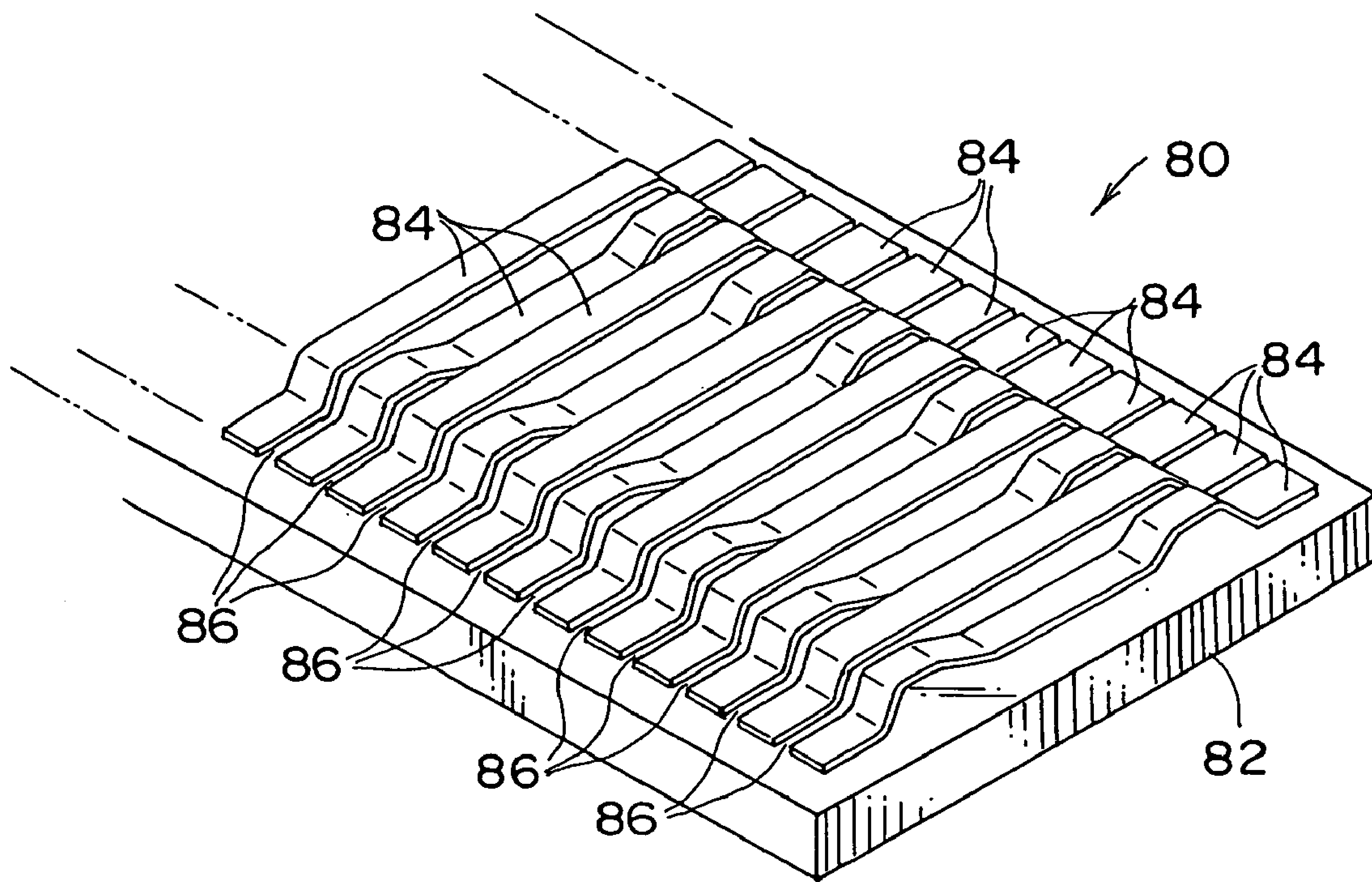


FIG.25B

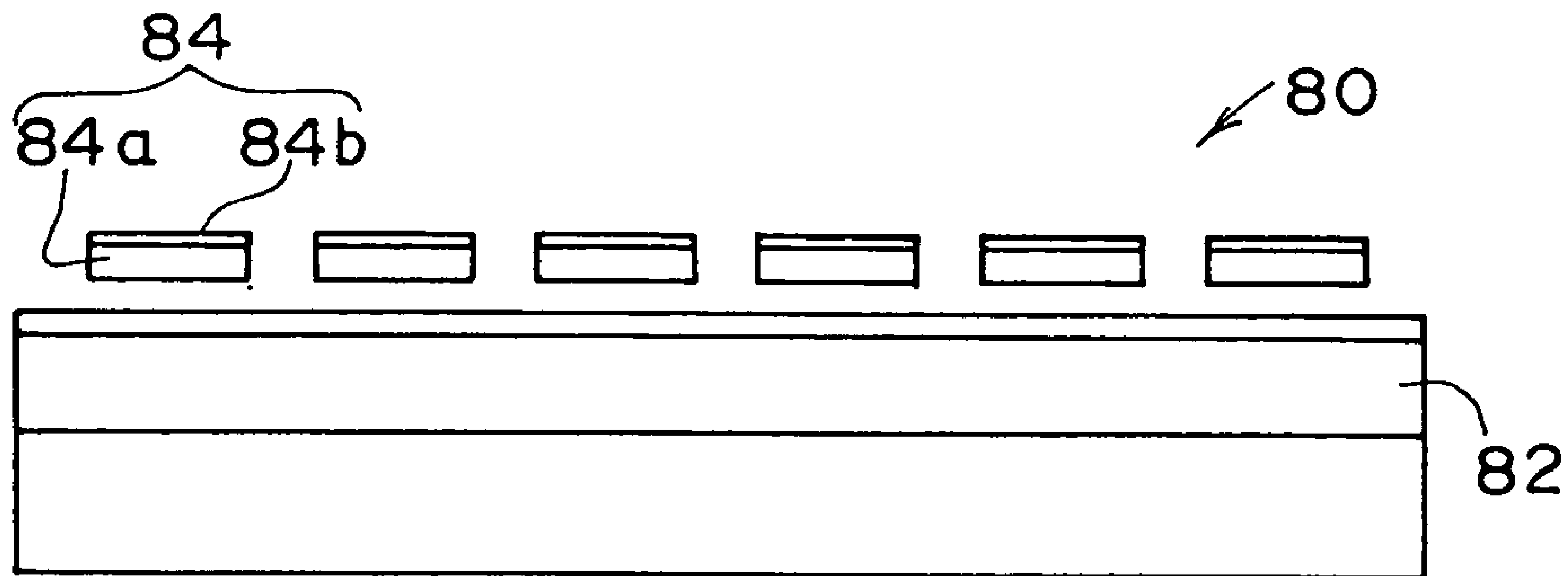
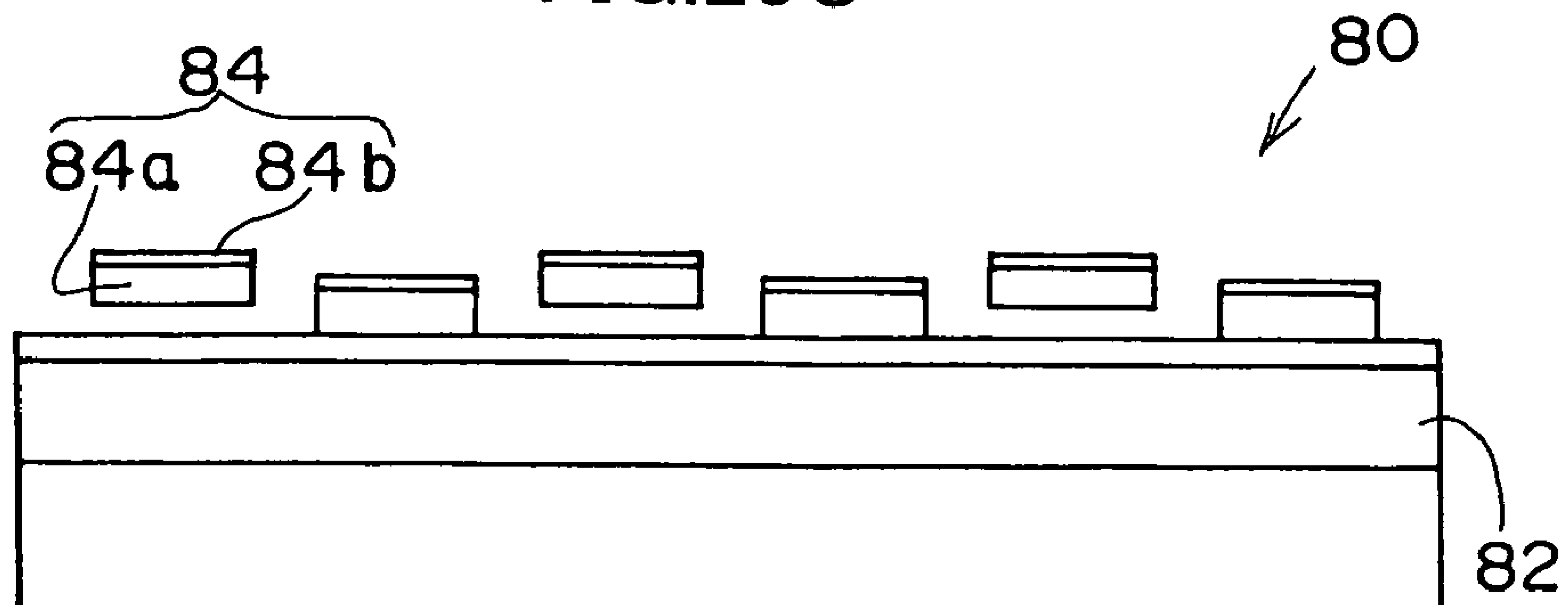


FIG.25C



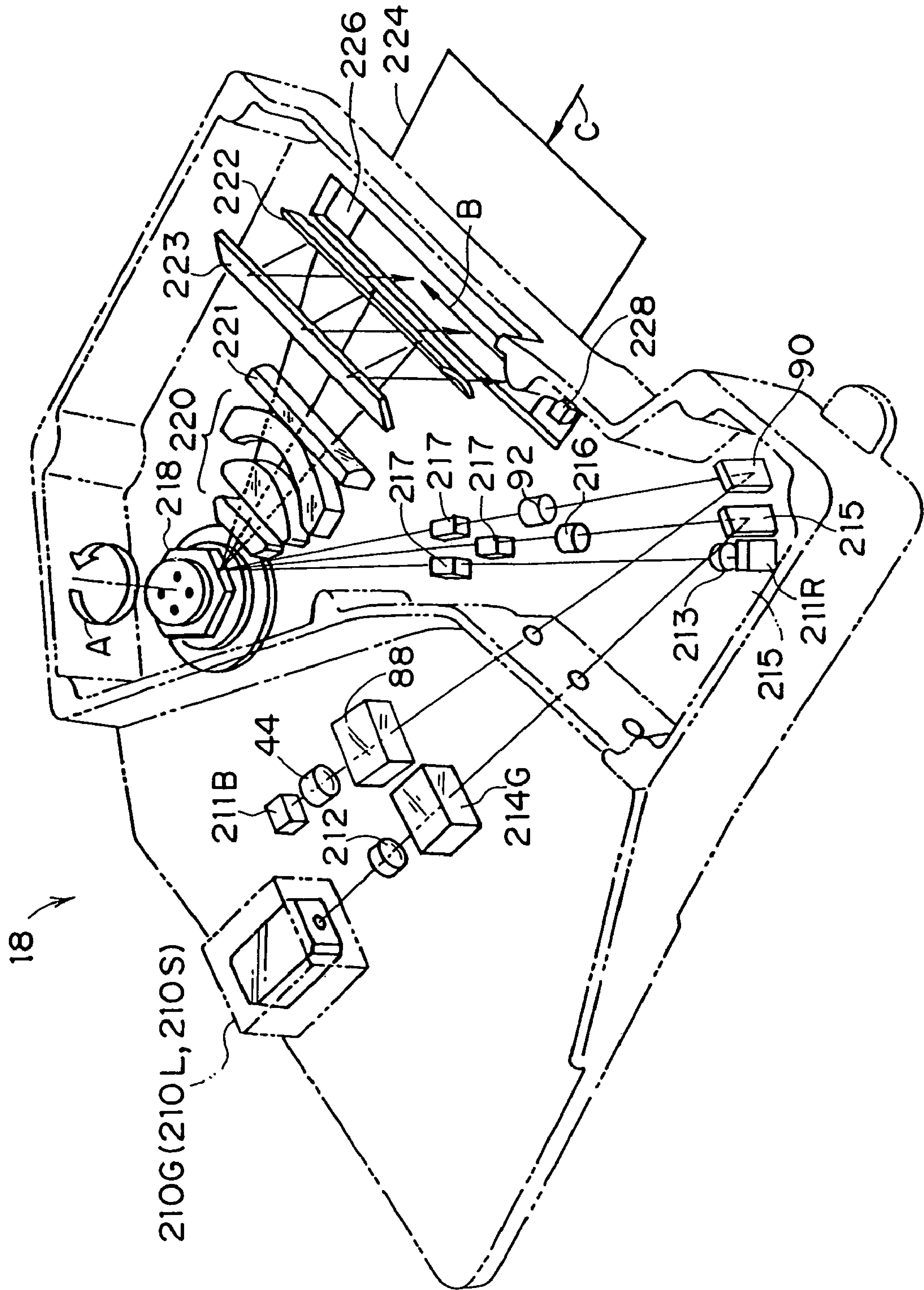


FIG.26
18
210G(210L, 210S)
211B
44
88
212
214G
213
211R
215
215
216
92
217
217
217
90
228
218
220
221
223
222
226
224
A
B
C

FIG.27

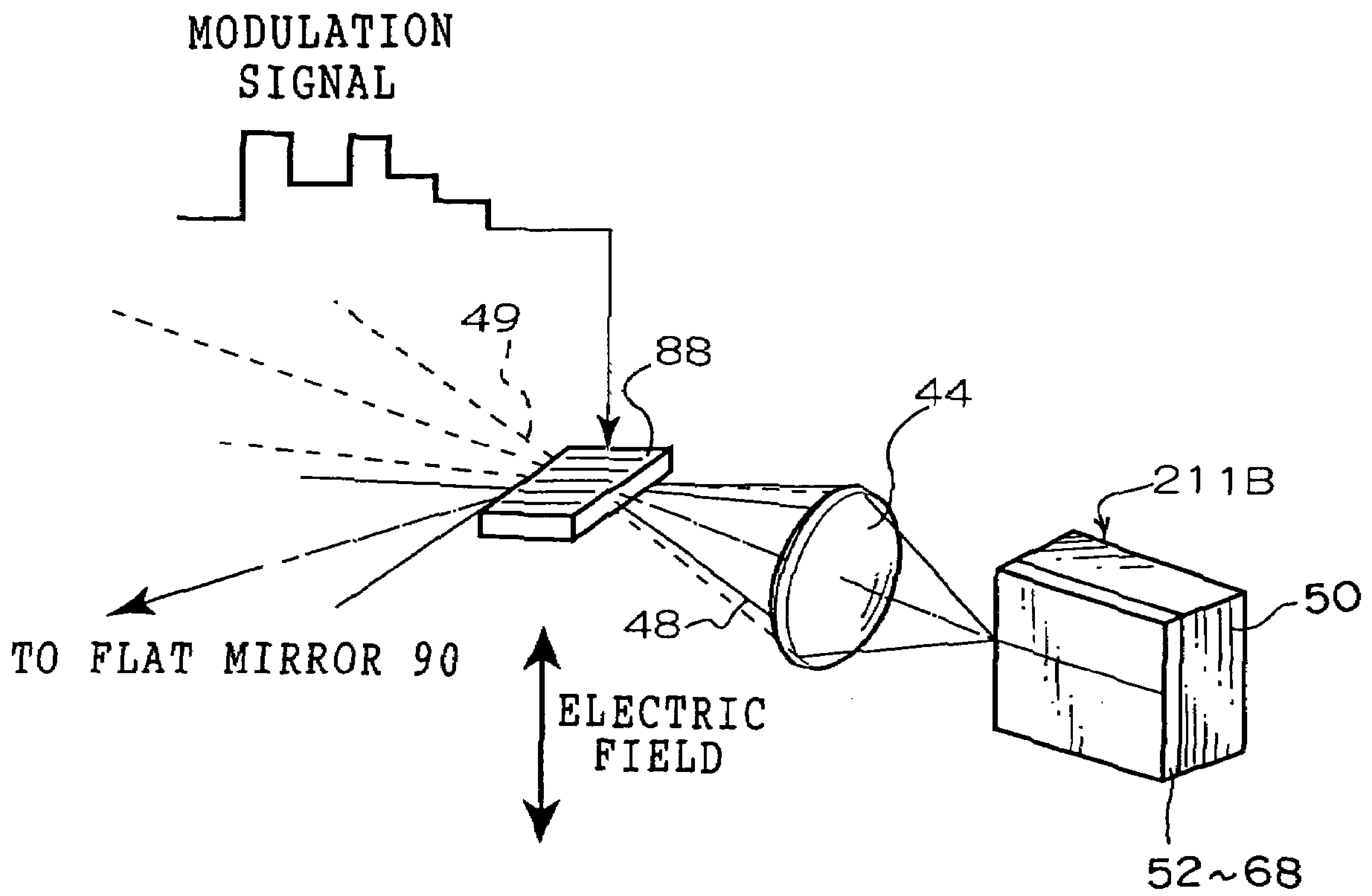


FIG.28A
PRIOR ART

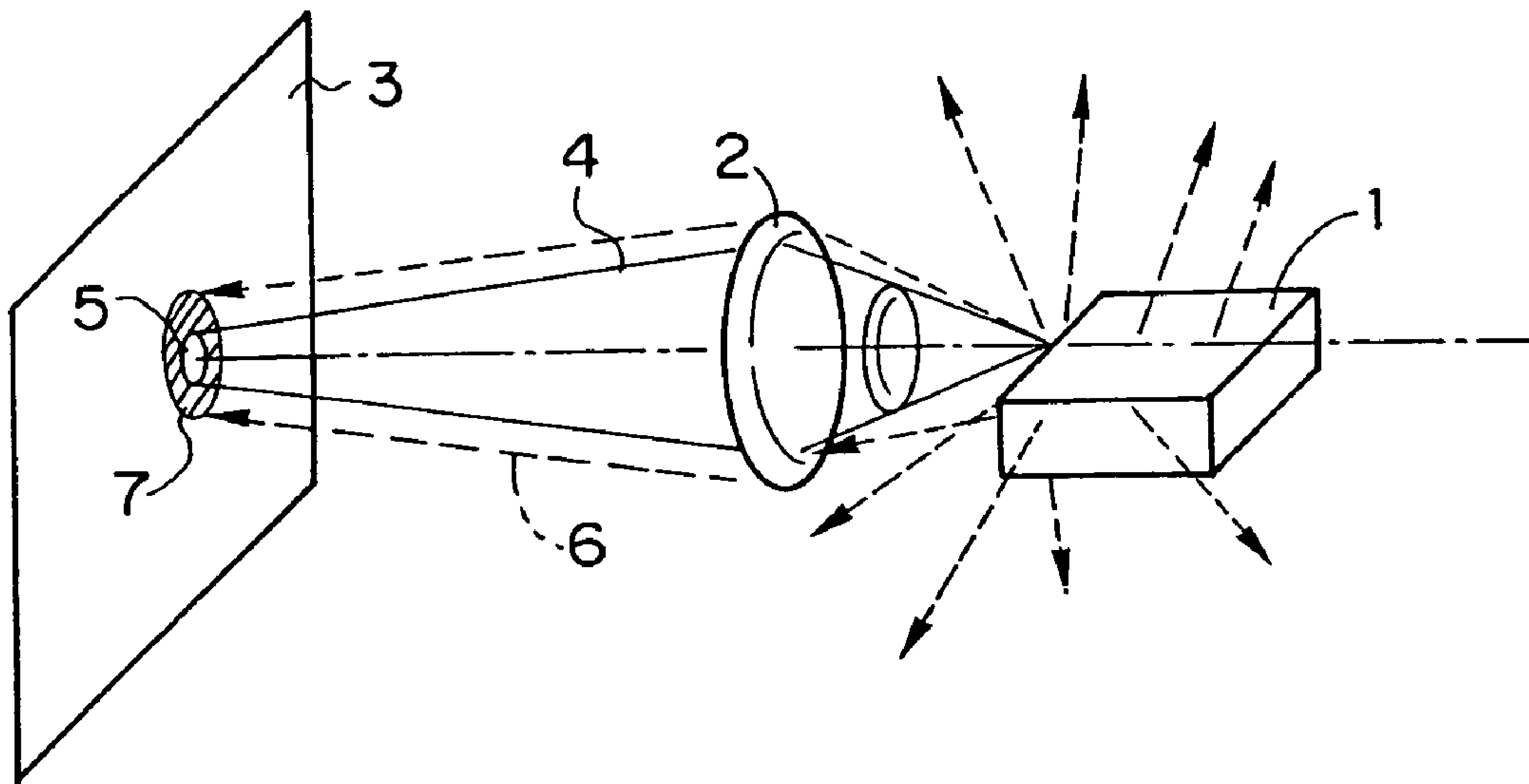


FIG.28B
PRIOR ART

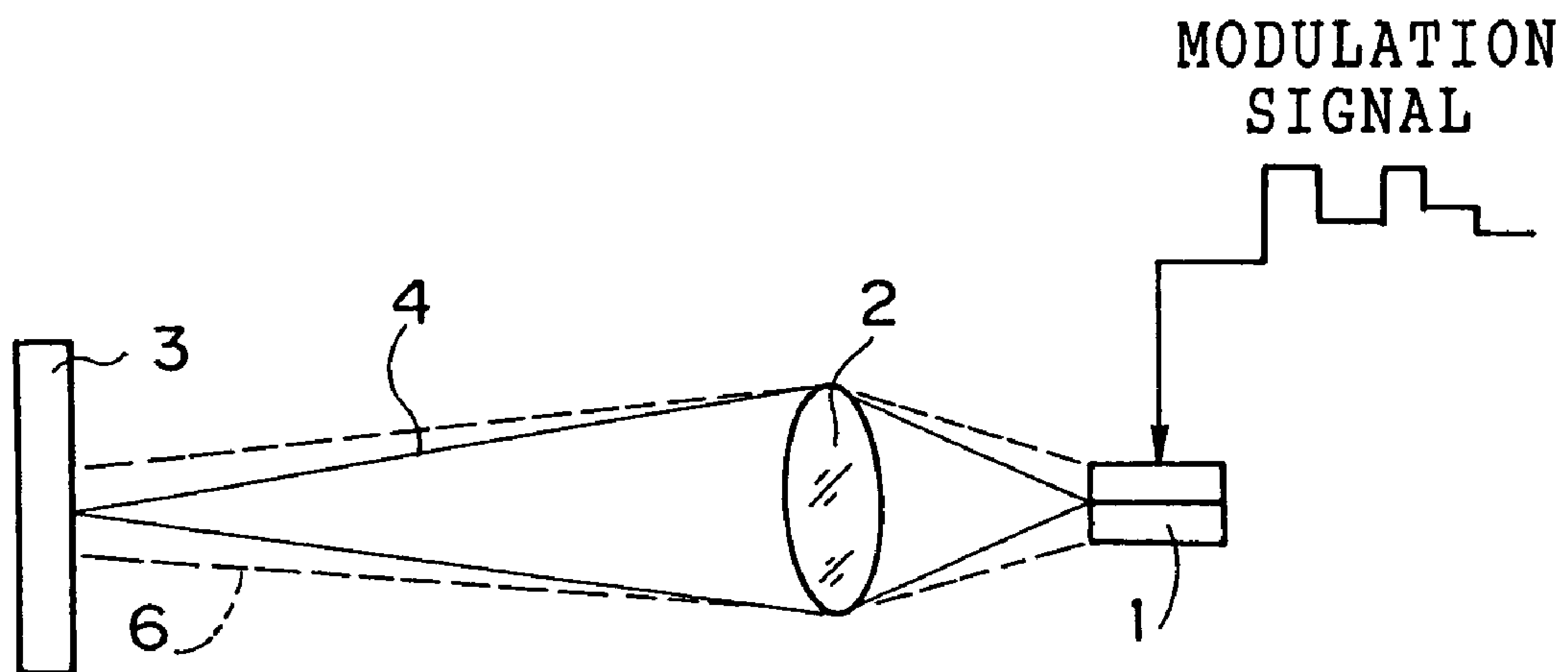


FIG.29

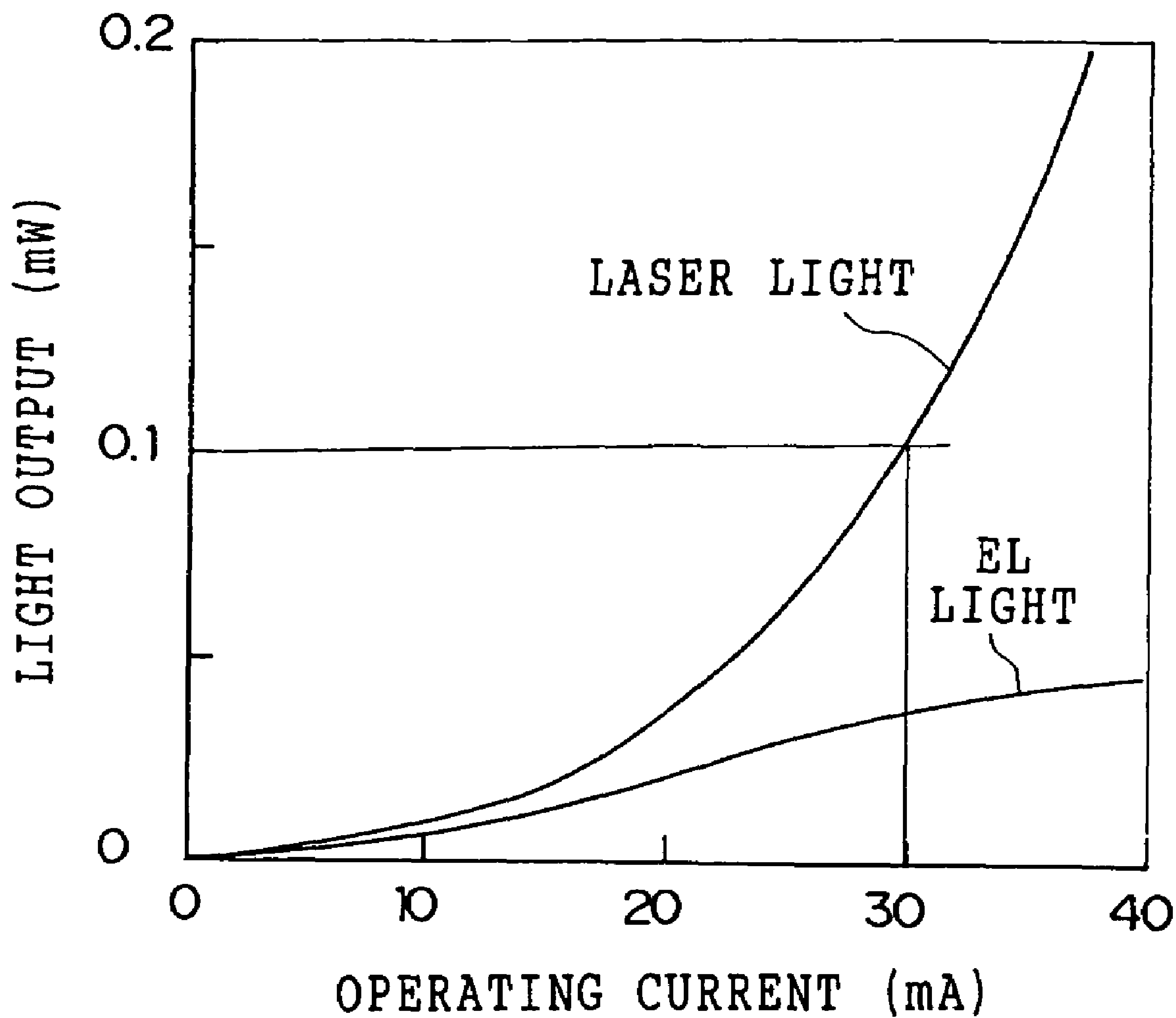


FIG.30A
PRIOR ART

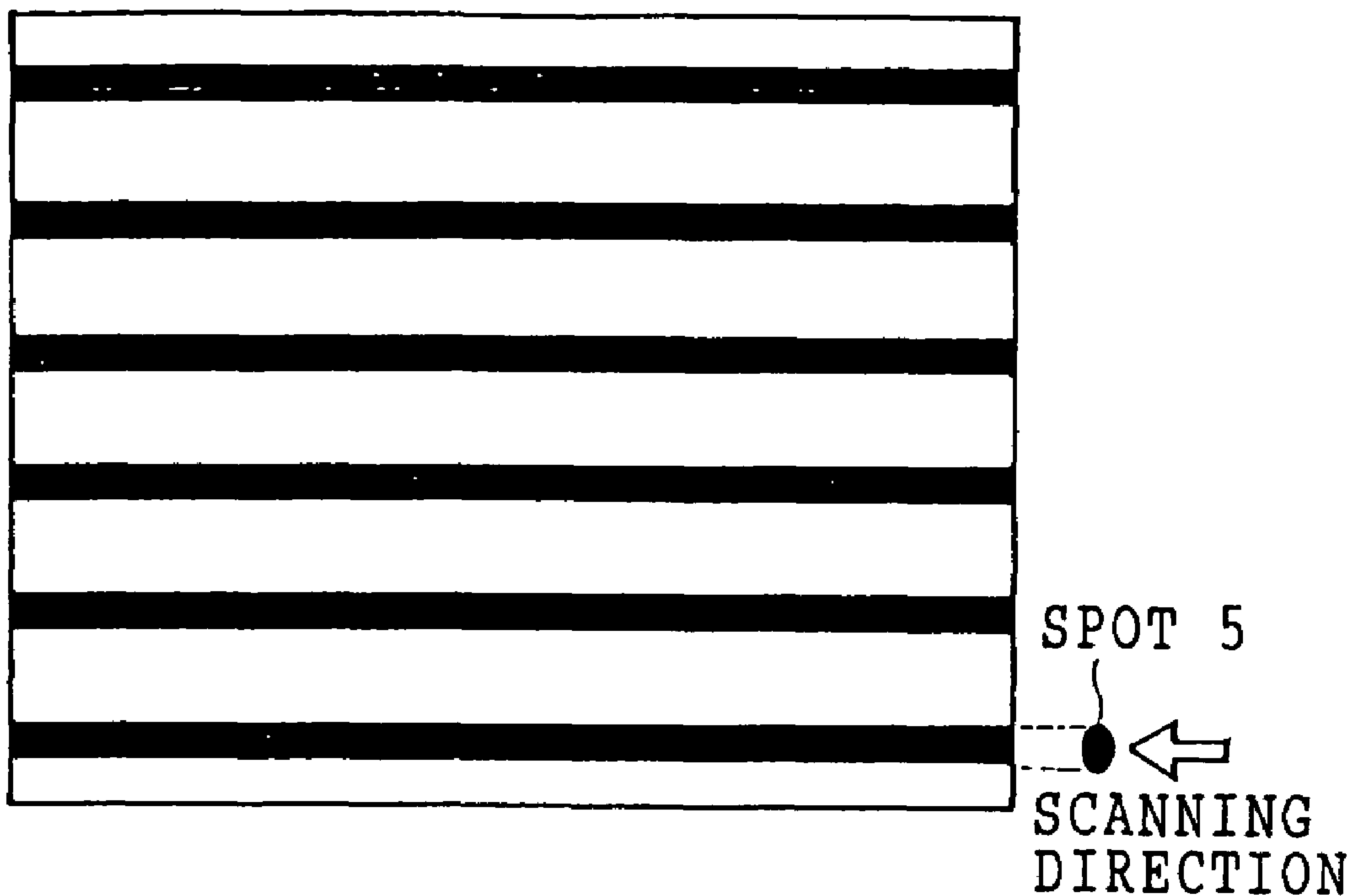


FIG.30B
PRIOR ART

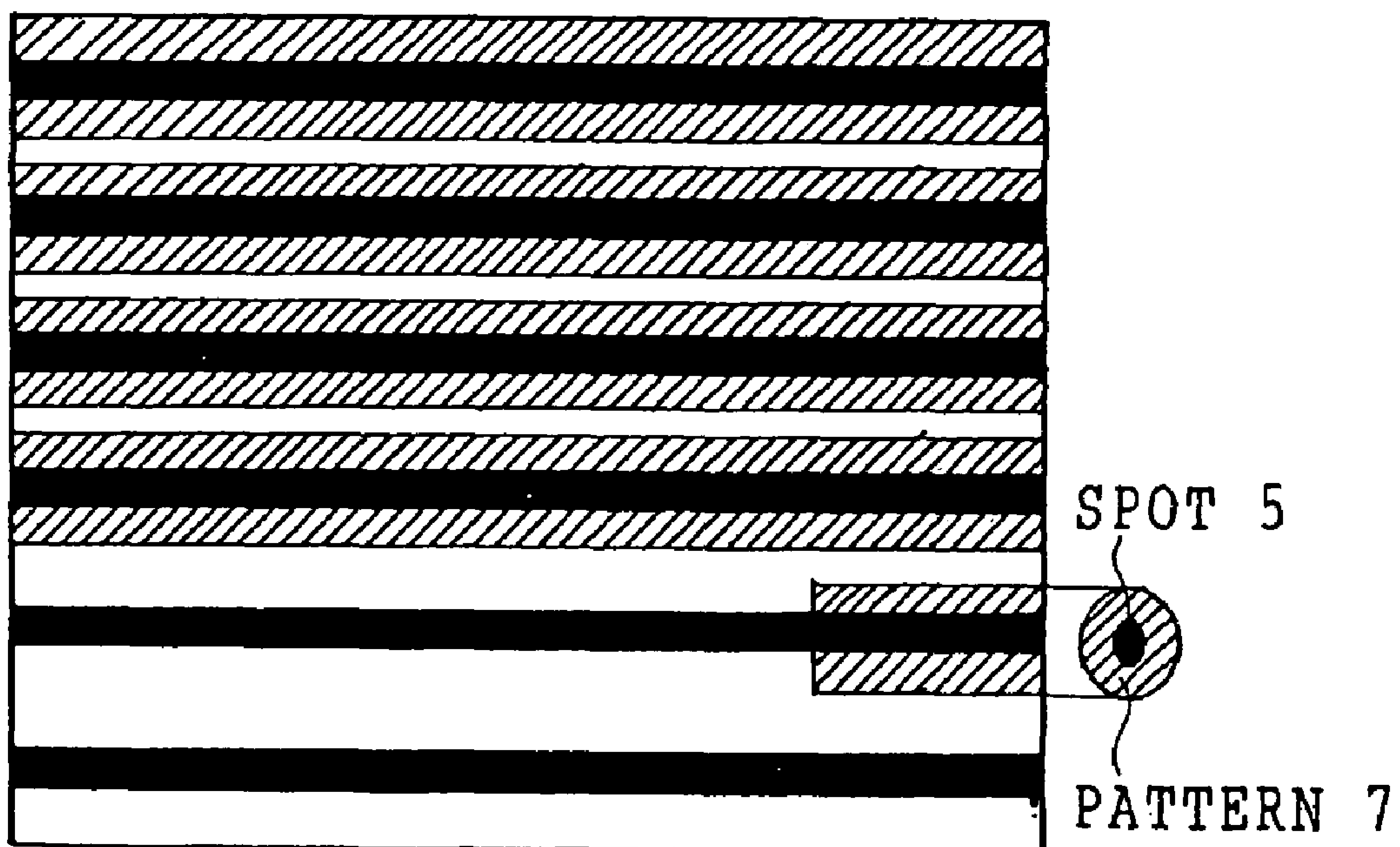


IMAGE EXPOSURE DEVICE AND LASER EXPOSURE DEVICE APPLIED THERETO

This is a divisional of application Ser. No. 10/329,762 filed Dec. 27, 2002 now U.S. Pat. No. 6,977,780.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an image exposure device, particularly an image exposure device that is disposed with a GaN based semiconductor laser, modulates a laser beam, and scan-exposes a recording material such as photosensitive material with the laser beam, and to a laser exposure device applied thereto.

2. Description of the Related Art

Image exposure devices that scan a recording material with light and expose an image thereon using a light source device that includes an edge emitting LED (a super luminescent diode (SLD) or the like) or a semiconductor laser taking as a structural material AlGaInP, AlGaAs, or InGaAsP of a GaAs substrate shape have been proposed.

In light source devices that use such materials, GaAs, which serves as the substrate with respect to an emission wavelength, is an absorbent material, and light absorbent materials such as InGaAs are also used in opposing electrodes. For this reason, light ordinarily becomes independently closed off in an emission region of a few microns in width, and there is a relatively small amount of stray light outside of striped regions due to the effect of the absorbent materials.

The development of semiconductor lasers having a short oscillation wavelength (referred to below as "short-wavelength lasers"), such as blue-violet semiconductor lasers, has advanced steadily, and the utilization of GaN based semiconductor lasers is growing near at hand. In edge emitting LEDs or semiconductor lasers using GaN material, a material such as sapphire or SiC that is transparent with respect to the emission wavelength is used for the substrate. For this reason, stray light reaching the edges of the chip is returned to a vicinity of an active region by reflection, and stray light of various patterns is produced by plural reflections.

FIG. **15** is a pattern diagram showing a GaN based semiconductor laser **90** being used for a light source in a silver halide exposure device that spot-scans using a polygon or the like. As shown in FIG. **15**, laser light emitted from the GaN based semiconductor laser **90** is collimated at a spot **194** of a predetermined size by a collimator lens **192**. However, stray light (so-called EL light) **198**, whose emission position and direction are random, cannot be collimated at the spot **194** and forms a blurry pattern **199**.

FIG. **16** illustrates the relation between drive current and light output of the spot **194** and the relation between drive current and light output of the blurry pattern **199**. As shown in FIG. **16**, a large amount of power is present at the blurry pattern **199** in a region of about 0.05 mW low exposure intensity that is critical in silver halide exposure methods.

In comparison to electrophotographic methods using photosensitive materials such as photosensitive drums, the blurry pattern **199** becomes a fatal defect (i.e., the photosensitive material reacts due to the stray light) in high-resolution silver halide exposure methods, which have extremely high sensitivity. For example, when a pattern (e.g., the striped pattern shown in FIG. **17**A) having a line width that is roughly the same as the diameter of the spot **194** is formed with a GaN based semiconductor laser, ordinarily an image is formed in stripes as shown in FIG. **17**A. However, as shown in FIG. **17**B, coloration also occurs between the stripes due to the blurry pattern **199**, and a remarkably degraded image whose sharpness has dropped and that is different from the expected image is formed.

Because the light amount of the blurry pattern resulting from the stray light is small, there are not many problems in area gradation such as in electrophotographic methods. However, in continuous-tone photosensitive materials such as those used in silver halide photography, a slight background leads to blurry characters and blurry images and remarkable degradation.

In exposure of silver halide methods, which are characterized by high-resolution images, it is necessary to reduce stray light that is inherent to GaN based semiconductor lasers and exerts an adverse, critical, and fatal impact on an image.

Exposure devices that expose photosensitive materials using a semiconductor laser are used for various purposes such as laser printing. In order to improve the quality of exposed images, it is effective to reduce as much as possible the spot diameter of the laser beam by reducing the wavelength itself of the laser light.

However, there is a problem in that, when a GaN based semiconductor laser is used for the light source in an exposure device, sharpness of the spot contour cannot be obtained due to the unintended stray light even if the beam diameter is reduced by operating the optical system. Particularly in silver halide methods, in which a continuous-tone high-resolution photographic image is formed by exposing a silver halide photosensitive material that is highly sensitive, lack of sharpness of the spot contour becomes a fatal problem in comparison to electrophotographic methods in which an image is structured by halftone dots.

For example, as shown in FIGS. **28**A and **28**B, when output light of a GaN based semiconductor laser **1** is collimated on a surface of a printing paper **3** by a lens **2**, laser-oscillated laser light **4** forms a spot **5** of a predetermined size. However, a pattern **7** having a contour that lacks sharpness is formed by EL light **6** whose emission position, direction and wavelength are random. Power of about 0.1 mW is sufficient to expose a silver halide photosensitive material that is highly sensitive. However, as shown in FIG. **29**, light intensity on the printing paper **3** is fairly large due to the EL light even in low exposure intensity regions where light intensity on the printing paper **3** is about 0.1 mW in the laser spot. For this reason, when a striped pattern having a line width that is equivalent to the diameter of a spot **5** shown in FIG. **30**A is formed, areas between the stripes are exposed by the EL light **6** and, as shown in FIG. **30**B, only images that have inferior clarity are obtainable.

SUMMARY OF THE INVENTION

The present invention was devised in consideration of the aforementioned problems. It is an object of the invention to provide an image exposure device that can limit stray light of a light source emitting a large amount of stray light.

It is another object of the invention to provide a light exposure device that can expose a photosensitive material to light in which EL light is reduced from output light of a gallium nitride semiconductor laser.

In order to achieve the aforementioned object, a first aspect of the invention is an image exposure device that uses a laser beam to scan-expose an image on photosensitive material, the image exposure device comprising: a GaN based semiconductor laser for emitting light that includes a

laser beam and emission light other than the laser beam; and a lens through which the laser light emitted from the GaN based semiconductor laser is irradiated onto the photosensitive material, wherein when a numerical aperture of the lens is NA, setting of the NA is conducted so that a total angle ϕ of a widening angle of a median intensity of the laser beam emitted from the GaN based semiconductor laser satisfies $\phi \geqq (\sin^{-1}NA)\times 2$.

According to the first aspect of the invention, the laser beam emitted by the GaN based semiconductor laser (e.g., a GaN based semiconductor laser that emits a blue laser beam) is transmitted through the lens and irradiated on the photosensitive material to form a beam spot. Thus, an image is exposed. Because the GaN based semiconductor laser emits light other than the laser beam, stray light is emitted as described above. For this reason, when the laser beam is irradiated on the photosensitive material, stray light is also collimated around the beam spot.

Thus, the widening total angle of light defining the numerical aperture of the lens is set so that the widening total angle of the light defining the numerical aperture of the lens becomes equal to or less than the widening total angle of median intensity of the laser beam emitted from the GaN based semiconductor laser. That is, by making the widening total angle of light defining the numerical aperture of the lens smaller than the widening total angle of median intensity of the laser beam emitted from the GaN based semiconductor laser, it is possible to prevent stray light that is emitted equal to or greater than the widening total angle of median intensity of the laser beam emitted from the GaN based semiconductor laser from being transmitted through the lens. Therefore, it is possible to suppress light around the beam spot resulting from stray light emitted from the GaN based semiconductor laser and to improve the sharpness of the exposed image.

When a ratio R between the widening total angle ϕ defining the numerical aperture NA of the lens and the widening total angle ϕ of median intensity of the laser beam emitted from the GaN based semiconductor laser is defined as $R=(\sin^{-1}NA)\times 2/\phi$, it is prefer to conduct the aforementioned setting so that $2.0 \geqq R \geqq 0.58$.

That is, when the widening total angle defining the numerical aperture NA of the lens is made smaller than the widening total angle of median intensity of the laser beam emitted from the GaN based semiconductor laser, it is possible to obtain a modulation range necessary for exposure, but side lobes are generated at the beam profile of the GaN based semiconductor laser, whereby the exposed image becomes degraded. Thus, by providing a lower limit that does not adversely impact image quality, it is possible to secure a modulation range necessary for exposure and improve the sharpness of the exposed image.

A luminous flux limiter for limiting the luminous flux of the light may be disposed on the optical path of light emitted from the GaN based semiconductor laser, whereby it becomes possible to use the luminous flux limiter to suppress even further stray light irradiated on the photosensitive material.

Setting of the widening total angle of light defining the numerical aperture of the lens may be conducted by setting the numerical aperture of the lens itself, or by disposing a numerical aperture limiter for limiting the numerical aperture of the lens and setting the widening total angle of light defining the numerical aperture of the lens using the numerical aperture limiter. The limiting amount of the numerical aperture may be set by the transmittance area of a transmittance opening as a transmittance opening through which light is transmitted, or set by the reflectance area of a reflective mirror as a reflective mirror for reflecting light.

It is possible to use a silver halide photosensitive material having the characteristic of $3.5 \geqq \gamma \geqq 2.5$ as the photosensitive material.

In order to achieve the aforementioned object, a second aspect of the invention is an image exposure device that uses a laser beam to scan-expose an image on photosensitive material, the image exposure device comprising: a GaN based semiconductor laser for emitting light that includes a laser beam and emission light other than the laser beam; a drive for driving the GaN based semiconductor laser so that the light is emitted at an amount that is equal to or greater than an amount necessary to be able to expose the photosensitive material even if the light is reduced; and a limiter for limiting the light emitted from the GaN based semiconductor laser so that the light irradiated onto the photosensitive material is of an amount necessary for exposure, the limiter being disposed in an optical path of the light that is emitted from the GaN based semiconductor laser and irradiated onto the photosensitive material.

As shown in FIG. **16**, the GaN based semiconductor laser (e.g., a GaN based semiconductor laser that emits a blue laser beam) has the characteristic of emitting an extremely large amount of stray light (blurry pattern). As shown in FIG. **16**, whereas the light output of a light spot increases abruptly, there is little increase in the light output of stray light (blurry pattern) with respect to an increase in drive current. Thus, in the second aspect of the invention, even if light emitted from the GaN based semiconductor laser is reduced, the GaN based semiconductor laser is driven by the drive to that an amount of light equal to or greater than that capable of exposing the photosensitive material is emitted. That is, by driving the GaN based semiconductor laser as a light amount exceeding a light amount for exposing an image on the photosensitive material, it is possible for the percentage occupied by stray light included in light emitted from the GaN based semiconductor laser to be reduced in comparison to the light output of the light spot collimated on the photosensitive material.

Also, it is possible to conduct exposure at an proper light amount by the light irradiated on the photosensitive material being limited to a light amount necessary for exposure due to the limiter disposed on the optical path of the light emitted from the GaN based semiconductor laser and irradiated on the photosensitive material. That is, by increasing the drive current of the GaN based semiconductor laser and limiting the amount of light emitted from the GaN based semiconductor laser, stray light can be suppressed.

The limiter may be an optical system disposed on the optical path of light that is emitted from the GaN based semiconductor laser and irradiated on the photosensitive material. The limiter may also increase light loss of the optical system and limit the amount of light so that the light is limited to an amount necessary for exposure. The optical system can include as the limiter light filters and half mirrors.

The invention may be configured so that the drive drives the GaN based semiconductor laser at 0.5 mW or greater and the limiter limits 80% or more of the light emitted from the GaN based semiconductor laser.

Generally, it is necessary for the exposure surface light amount in a standard mini-laboratory to be 100 μW or less. Thus, the drive current drives the GaN based semiconductor laser at 0.5 mW or more, which generates an amount of light equal to or greater than the light amount necessary for exposure, and the limiter limits 80% or more of the 0.5 mW

light amount, i.e., the light emitted from the GaN based semiconductor laser, whereby it is possible to obtain an exposure surface light amount necessary in a standard mini-laboratory (about 100 μW).

Using a silver halide photosensitive material as the photosensitive material, it is possible to apply the invention to an image exposure device in which exposure is conducted at an exposure resolution of 300 to 600 dpi and at a scanning speed of 500 to 1500 m/sec.

Also, the light amount can be limited by at least one of a density filter, a half mirror, a coated surface of the lens, and a reflective surface of a mirror.

In order to achieve the aforementioned object, a third aspect of the invention is a laser exposure device comprising: a semiconductor laser that comprises gallium nitride and emits stray light other than laser light when emitting laser light; and a diffraction unit for diffracting the laser light emitted from the semiconductor laser in a predetermined direction that is different from that of the stray light.

The semiconductor laser used in the light source of the laser exposure device comprises a gallium nitride material and emits stray light other than laser light when emitting the laser light. The diffraction unit diffracts laser light emitted from the semiconductor laser in a predetermined direction that is different from that of the stray light. Because the photosensitive material is exposed by this diffracted light, it is possible to expose the photosensitive material with a light in which stray light is reduced from the output light of the gallium nitride semiconductor laser.

The diffraction unit may be one that includes both the functions of diffracting laser light emitted from the semiconductor laser and spatially modulating the intensity of the diffracted light in correspondence to image data. For example, a diffraction unit that includes the function of controlling the gradient index or the shape of diffraction grooves and modulating the intensity of diffracted light can be used.

A spatial light modulator such as a grating light valve (GLV) can be used as the diffraction unit including the function of controlling the shape of diffraction grooves and spatially modulating the intensity of the diffracted light. The GLV comprises solid micro elements having formed thereon a first reflective surface and moveable micro elements having formed thereon a second reflective surface that are alternatingly disposed along a predetermined direction on a substrate surface. When an electrostatic force corresponding to a modulation signal acts, the moveable micro elements move, the distance between the first reflective surface and the second reflective surface is altered, and incident light of a predetermined wavelength is diffracted in a predetermined direction by an interference effect.

It is possible to use an acoustooptic modulator as the diffraction unit including the function of controlling the gradient index and spatially modulating the intensity of the diffracted light. When an acoustooptic modulator is used, the thickness of the portion on which the gradient index is formed is preferably 0.05 mm to 0.1 mm.

It is preferable to dispose the semiconductor laser so that the electric field faces a direction substantially orthogonal to an effective diffraction grating surface of the diffraction unit. By making the electric field incident on the diffraction grating surface, diffraction efficiency is maximized. Also, a spatial modulator that is separate from the diffraction unit for diffracting laser light and spatially modulates the intensity of the diffracted light can also be disposed between the semiconductor laser and the photosensitive material.

Particularly remarkable effects can be obtained when the laser exposure device of the invention is applied to a highly sensitive photosensitive material that is exposed by density gradation, such as a silver halide photosensitive material.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing the schematic structure of a digital laboratory system pertaining to an embodiment of the invention;

FIG. **2** is an oblique perspective view showing an outer appearance of the digital laboratory system pertaining to the embodiment of the invention;

FIG. **3** is an oblique perspective view showing the schematic structure of a laser printer;

FIG. **4** is a cross sectional pattern diagram showing the detailed structure of a GaN based semiconductor laser;

FIG. **5** is a pattern diagram showing an optical system of the GaN based semiconductor laser;

FIG. **6**A is a diagram showing θ defining a numerical aperture;

FIG. **6**B is a diagram showing a total angle ϕ of an angle in a median intensity of light of a laser light source;

FIG. **7** is a graph showing a beam profile when a ratio R is varied;

FIGS. **8**A to **8**C are graphs showing a beam profile when the ratio is varied;

FIG. **9** is a graph showing the relation between the ratio R and density contrast;

FIG. **10** is a block diagram showing a control unit in the laser printer;

FIG. **11** is a view showing the optical system further disposed with a luminous flux limiter;

FIG. **12** is a view showing an example of the example system disposed with the luminous flux limiter;

FIG. **13** is a view showing another example of the luminous flux limiter;

FIG. **14** is a view showing an example of a numerical aperture limiter using a folding mirror;

FIG. **15** is a pattern diagram when a GaN based semiconductor laser is used as a light source in a silver halide exposure device for spot-scanning using a polygon or the like;

FIG. **16** is a graph showing the relation between light output of a spot and a drive current and the relation between light output of a blurry pattern and a drive current;

FIG. **17**A is a diagram showing a striped pattern;

FIG. **17**B is a diagram showing an example in which the blurry pattern has colored the striped pattern;

FIG. **18** is an oblique perspective view showing the schematic structure of a laser printer pertaining to a second embodiment of the invention;

FIG. **19** is a graph for explaining reduction in a ratio between light output of stray light and light output of a light spot when the drive current is increased with regard to drive current characteristics/light output of a GaN based semiconductor laser;

FIG. **20** is an oblique perspective view showing the schematic structure of a laser printer pertaining to a third embodiment of the invention;

FIG. **21** is a schematic diagram showing a principle in which EL light is separated from output light of a B-color laser light source in the laser printer shown in FIG. **20**;

FIG. **22** is a cross sectional diagram showing a layered structure of the GaN based semiconductor laser;

FIG. **23** is a graph showing the relation between a drive current and light strength on a printing paper due to output light from the B-color laser light source;

FIG. **24** is a schematic diagram showing a structure for separating EL light from output light of a B-color laser light source in a laser printer of a digital laboratory system pertaining to a fourth embodiment of the invention;

FIG. **25**A is an oblique perspective view showing the schematic structure of a grating light valve (GLV);

FIG. **25**B is a view for explaining the operational principle of the GLV;

FIG. **25**C is a view for explaining the operational principle of the GLV;

FIG. **26** is an oblique perspective view showing the structure of an optical system in a laser printer of a digital laboratory system pertaining to a fifth embodiment of the invention;

FIG. **27** is an oblique perspective view showing a structure for separating EL light from output light of a B-color laser light source in the laser printer shown in FIG. **26**;

FIG. **28**A is an oblique perspective view showing a printing paper being scanned by a conventional exposure device using a GaN based semiconductor laser;

FIG. **28**B is a cross sectional view along an optical axis of FIG. **28**A;

FIG. **29** is a graph showing the relation between a drive current and light strength on a printing paper due to output light from the GaN based semiconductor laser;

FIG. **30**A is a view showing a striped pattern with a line width that is the same as a diameter of a laser spot; and

FIG. **30**B is a view showing an image when the pattern of FIG. **30**A is scanned using a conventional exposure device using a GaN based semiconductor laser.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

An example of a first embodiment of the invention will be described in detail below with reference to the drawings. It should be noted that the present embodiment is one in which the invention is applied to a digital laboratory system.

(Schematic Description of Overall System)

FIG. **1** shows the schematic structure of a digital laboratory system **10** pertaining to an embodiment of the invention, and FIG. **2** shows the digital laboratory system **10** in perspective view. As shown in FIG. **1**, the digital laboratory system **10** comprises a line CCD scanner **14**, an image processor **16**, a laser printer **18** that serves as an image exposure device, and a processor **20**. As shown in FIG. **2**, the line CCD scanner **14** and the image processor **16** are integrated as an input section **26**, and the laser printer **18** and the processor **20** are integrated as an output section **28**.

The line CCD scanner **14** is for reading a film image (a negative image or a positive image visualized by developing and processing material on which a shot subject has been recorded) recorded on photographic photosensitive material (referred to below simply as "photographic film") such as photographic film (e.g., negative film or reversal film). For example, film images of 135 mm photographic film, 110 mm photographic film and photographic film in which a transparent magnetic layer is formed (240 mm photographic film: so-called APS film), 120 mm and 220 mm (brownie size) photographic film can be the reading target. The line CCD scanner **14** reads a film image of the aforementioned reading target with a 3-line color CCD and outputs R, G and B image data.

As shown in FIG. **2**, the line CCD scanner **14** is mounted on a work table **30**. The image processor **16** is housed within a housing **32** disposed below the work table **30**. An open/close door **34** is mounted at an opening in the housing **32**. The interior of the housing **32** is ordinarily covered by the open/close door **34**. The interior is exposed by swinging the open/close door **34** open, whereby it becomes possible to remove the image processor **16**.

A display **164** is mounted at a far side of the work table **30**, and two kinds of keyboards **166**A and **166**B are disposed. The keyboard **166**A is disposed in the work table **30**. The keyboard **166**B is stored within a drawer **36** of the work table **30** when not in use, and removed from the drawer **36** and superimposed on the keyboard **166**A when in use. When the keyboard **166**B is in use, a connector (not illustrated) attached to an end of a cord (signal line) that extends from the keyboard **166**B is connected to a jack **37** disposed in the work table **30**, whereby the keyboard **166**B is electrically connected to the image processor **16** via the jack **37**.

A mouse **40** is disposed on a work surface **30**U of the work table **30**. The mouse **40** is connected to the image processor **16** by a cord (signal line) that extends into the housing **32** through a hole **42** disposed in the work table **30**. The mouse **40** is stored in a mouse holder **40**A when not in use, and removed from the mouse holder **40**A and disposed on the work surface **30**U when in use.

Image data (scanned image data) outputted from the line CCD scanner **14** is inputted to the image processor **16**. It is also possible for image data obtained by shooting with a digital camera, image data obtained by reading an original (e.g., a reflection original) other than a film image with a scanner, and image data generated by a computer (all of these image data will be collectively referred to below as file image data) to be inputted to the image processor **16** from the outside (e.g., inputted through a storage medium such as a memory card, or inputted from other information processing devices through communication lines).

The image processor **16** carries out image processing such as various corrections with respect to image data inputted thereto, and inputs the image data to the laser printer **18** as image data for recording. The image processor **16** can also output image-processed image data to the outside as an image file (e.g., output image-processed image data to an information storage medium such as a memory card, or send image-processed image data to other information processing devices through communication lines).

The laser printer **18** is disposed with R, G and B laser light sources, irradiates printing paper with laser light modulated in response to the image data for recording inputted from the image processor **16**, and records an image (latent image) on the printing paper by scan-exposing the printing paper. The processor **20** carries out processing such as color development, bleach-fixing, rinsing, and drying of the printing paper on which an image has been recorded by the laser printer **18** scan-exposing the printing paper. Thus, an image is formed on the printing paper.

(Detailed Structure of the Laser Printer)

The structure of the laser printer **18** will next be described in detail. The structure of an optical system of the laser printer **18** is shown in FIG. **3**.

The laser printer **18** is disposed with three laser light sources—a laser light source **211**R, a laser light source **210**Q and a laser light source **211**B. The laser light source **211**R

comprises a semiconductor laser (LD) that emits laser light (referred to below as R laser light) of an R wavelength (e.g., 685 nm). The laser light source **210**G comprises an LD **210**L that serves as a laser light emitter and a wavelength conversion element (SHG) **210**S that serves as wavelength converter for converting laser light emitted from the LD **210**L to laser light of ½ the wavelength thereof. The oscillation wavelength of the LD **210**L is determined so that laser light (referred to below as G laser light) of a G wavelength (e.g., 532 nm) is emitted from the SHG **210**S. The laser light source **211**B comprises an LD that emits laser light (referred to below as B laser light) of a B wavelength (e.g., 440 nm).

A collimator lens **212** and an acoustooptic modulator (AOM) **214**G that serves as an outside modulator are successively disposed at a laser light emission side of the laser light source **210**G The AOM **214**G is disposed so that laser light made incident thereon passes through an acoustooptic medium, and is connected to an AOM driver (not illustrated). When a high-frequency signal is inputted from the AOM driver, an ultrasonic wave corresponding to the high-frequency signal is propagated through the acoustooptic medium, diffraction occurs due to an acoustooptic effect acting on the laser light passing through the acoustooptic medium, and laser light of a strength corresponding to the amplitude of the high-frequency signal is emitted from the AOM **214**G as diffracted light.

A flat mirror **215** is disposed at a laser light emission side of the AOM **214**G, and a spherical lens **216**, a cylindrical lens **217**, and a polygon mirror **218** are successively disposed at a laser light emission side of the flat mirror **215**. G laser light that is emitted from the AOM **214**G as diffracted light is reflected by the flat mirror **215**, reflected to a predetermined position on a reflective surface of the polygon mirror **218** via the spherical lens **216** and the cylindrical lens **217**, and then reflected by the polygon mirror **218**.

A collimator lens **213** and a cylindrical lens **217** are successively disposed at laser light emission sides of the laser light sources **211**R and **211**B. Laser light emitted from the laser light sources **211**R and **211**B is collimated by the collimator lenses **213**, irradiated on substantially the same position as the aforementioned predetermined position on the reflective surface of the polygon mirror **218** via the cylindrical lenses **217**, and reflected by the polygon mirror **218**.

Three laser lights of R, G, and B reflected by the polygon mirror **218** successively pass through an f θ lens **220** and a cylindrical lens **221**, are reflected by a cylindrical mirror **222**, reflected substantially vertically downwards by an angled mirror **223**, and irradiated on printing paper **224** via an opening **226**. It should be noted that the angled mirror **223** may be omitted so that the laser lights are directly reflected substantially vertically downwards by the cylindrical mirror **222** and irradiated on the printing paper **224**.

A scanning initiation detection sensor (referred to below as an SOS detection sensor) **228** that detects R laser light arriving through the opening **226** is disposed near a position at which scan-exposure is initiated on the printing paper **224**. The reasons that the laser light that the SOS detection sensor **228** detects is R laser light are because the printing paper is least sensitive to R laser light and R laser light can be reliably detected because the light amount of R laser light is maximized, and because R laser light reaches the SOS detection sensor **228** most quickly in scanning by the rotation of the polygon mirror **218**. In the present embodiment, the signal outputted from the SOS detection sensor **228** (referred to below as the sensor output signal) is ordinarily at a low level and reaches a high level only when R laser light is detected.

The detailed structure of the laser light source **211**B pertaining to the present embodiment will next be described. FIG. **4** is a cross sectional pattern diagram of the laser light source **211**B pertaining to the embodiment of the invention. It should be noted that, in FIG. **4**, W**1**=1.7 μm, W**2**=300 μm, H**1**=about 0.9 μm, H**2**=about 3.5 μm, and H**3**=100 μm.

The laser light source **211**B comprises a InGaN based semiconductor laser. As shown in FIG. **4**, a low-defect GaN substrate layer is formed on a sapphire c surface substrate (by a method disclosed in S. Nagahama, et. al., Jpn. Appl. Phys. Vol. 39, No. 7A, p. L347 (2000)).

Next, using MOCVD at atmospheric pressure, an n-GaN buffer layer (Si-doped, 5 μm) **70**, an n-In 0.1 Ga 0.9 N buffer layer (Si-doped 0.1 μm) **66**, an a-A 10.1 Ga 0.9 N cladding layer (Si-doped, 0.45 μm) **64**, an n-GaN light guide layer (Si-doped, 0.04 to 0.08 μm) **62**, an undoped active layer **60**, a p-GaN light guide layer (Mg-doped, 0.04 to 0.08 μm) **58**, a p-A 10.1 Ga 0.9 N cladding layer (Mg-doped, 0.45 μm) **56**, and a p-GaN capping layer (Mg-doped, 0.25 μm) are deposited. The active layer **60** is a double quantum well structure of undoped In 0.05 Ga 0.95 N (10 nm), undoped In 0.23 Ga 0.77 N quantum well structure (3 nm), undoped In 0.05 Ga 0.95 (5 nm), undoped In 0.23 Ga 0.77 N quantum well structure (3 nm), undoped In 0.05 Ga 0.9 N (10 nm), undoped A 10.1 Ga 0.9 N (10 nm). Next, a resist ripe of about 1.7 μm is etched and formed by reactive ion beam etching (RIBE) using chlorine ions at a distance of 0.1 μm from the p-GaN light guide layer **58** in the p-A 10.1 Ga 0.9 N cladding layer by photolithography and etching. Next, an SiN film **52** is formed over the entire surface by plasma CVD, and unnecessary portions on the ridge are removed by photolithography and etching. Thereafter, p-type impurities are activated by heating in a nitrogen gas atmosphere. Thereafter, the epilayer other than portions including light emission regions are etched and removed by RIBE using chlorine ions until the n-GaN buffer layer **70** is exposed. Thereafter, Ti/Al/Ti/Au, serving as an n-electrode **68**, and Ni/Au, serving as a p-electrode **50**, are vacuum-evaporated and annealed in nitrogen to form ohmic electrodes. Resonator ends are formed by cleavage. In the present embodiment, the oscillation wavelength is 440 nm, and the beam emission angle median total angle in a direction orthogonal to the junction is 34 degrees. It should be noted that it is also possible to use a sapphire substrate of an insulator. It is also possible to produce a similar structure on a conductive substrate such as SiC. Moreover, it is also possible to reduce translocation of oscillation stripe regions using epitaxially lateral over growth (ELOG) (reference document: Matsushita, *Optronics,* (2000) No. 1, p. 62).

Next, the optical system of the laser light source (the aforementioned GaN based semiconductor laser) **211**B pertaining to the present embodiment will be described in detail. FIG. **5** is a pattern diagram showing the optical system of the GaN based semiconductor laser. In FIG. **5**, in order to simplify the optical system of the GaN based semiconductor laser, a collimator optical system **72** is shown as an optical system including the collimator lenses **213**, the cylindrical lenses **217**, the polygon mirror **218**, the f θ lens **220**, the cylindrical lens **221**, the cylindrical mirror **222**, and the angled mirror **223**.

As shown in FIG. **5**, B laser light emitted from the laser light source **211**B is irradiated on the printing paper **224** via the collimator optical system **72**. Although B laser light is irradiated on the printing paper **224** using the GaN based

semiconductor laser in the present embodiment, as mentioned above, the laser light source **211**B comprising the GaN based semiconductor laser includes the characteristic of emitting an extremely large amount of stray light. Therefore, blurring resulting from the stray light arises at the beam spot periphery irradiated on the printing paper **224** and image quality is lowered by the stray light.

Thus, in the present embodiment, in order to limit stray light emitted from the laser light source **211**B, a numerical aperture NA of the collimator optical system **72** (in the present embodiment, the collimator lenses **213**) is limited. It should be noted that limitation of the numerical aperture NA may be conducted by changing the numerical aperture of the collimator lenses **213** themselves, or by disposing an opening **73** through which laser light passes at the laser light incidence side of the collimator lens **213**, as shown in FIG. **5**. In the latter case, it is possible to limit the numerical aperture using the area of the opening.

Because, as shown in FIG. **6**A, the numerical aperture NA of the lens is generally defined as NA=n×sin θ (where n=1 assuming a refractive index and within the air) when the half angle of the aperture angle is θ, the half angle θ of the widening angle of the light defining the numerical aperture NA is represented as θ=sin−1 (NA), and when it comes to the total angle ϕ (see FIG. **6**B) of the angle in the median intensity of B laser light emitted by the laser light source **211**B, a ratio R with the total angle 2θ of the widening angle of the light defining the numerical aperture NA of the collimator optical system **72** (in the present embodiment, the collimator lenses **213**) is represented by the equation below.

$$R=\sin^{-1}(NA)\times 2/\phi$$

In the present embodiment, because a large amount of stray light is emitted from the laser light source **211**B, the numerical aperture of the lens NA is set such that NA and the total angle ϕ of the widening angle of the median intensity of laser beam satisfy the condition: $\phi \geqq (\sin^{-1} NA)\times 2$.

In particular, the ratio R between the total angle ϕ of the widening angle in the median intensity of B laser light emitted from the laser light source **211**B and the total angle 2θ of the widening angle of light defining the numerical aperture NA of the collimator optical system **72** is set to 2 or greater.

The ratio R is preferably set to 2.0≧R≧0.58. For example, in the present embodiment, the total angle ϕ of the widening angle in the median intensity of B laser light emitted from the laser light source **211**B is 30 degrees, and measurement results of beam shapes and current/light amount characteristics when the collimator lenses **213** of numerical apertures NA 0.75, 0.5 and 0.15 were used are shown in FIGS. **7** and **8**. In FIG. **7**, current/light amount characteristics are shown when the ratio R is 3.24, 2.0 and 0.58 corresponding to when the numerical aperture is 0.75, 0.5, and 0.15. In FIG. **8**, beam profiles are shown when the ratio R is 3.24, 2.0, and 0.58.

Generally, when exposing a silver halide photosensitive material in which the photosensitive material characteristic γ is 2.5 to 3.5, a modulation range of 2.01 logE or greater is necessary. As shown in FIG. **7**, when the ratio R is made smaller, it is possible to obtain a modulation range of about 2.01 log E when R=2.0. When the ratio R is further made smaller, the modulation range expands but, as shown in FIG. **8**C, side lobes appear at the beam profile and the sharpness of the exposed image drops because the ratio at which B laser light emitted from the laser light source **211**B is kicked rises due to the collimator optical system **72**.

Here, consideration will be given to a case in which exposure is conducted at a resolution of 300 dpi. The beam diameter defined when the light intensity in this case is 1/e2 is made the same as a pixel size 84.6 μm of 300 dpi, the ratio R of the exposure beam is altered, the amount of the side lobes is controlled, an exposure test is conducted, and the experiment results in which the impact on image quality was investigated are shown in FIG. **9**.

In FIG. **9**, results are shown in which the ratio R was altered to 2.0 to 0.30, a rectangular wave pattern was exposed, and changes in the density contrast thereof were investigated. A case in which exposure was conducted with a beam having no side lobes was taken as 100%, and the drop in density contrast is shown in numerical values. As a result of evaluating density contrast in terms of image quality, with respect to levels at which image quality degradation was visually recognizable as a significant difference, it was understood from the experiment that image quality degradation was remarkable contrast deterioration of less than 75%. When the lower limit of image quality degradation was 75% of contrast deterioration, 0.58 became the lower limit of the ratio R. That is, by setting the ratio R that can obtain a modulation range necessary for exposure to 2.0≧R≧0.58, it is possible to control image quality degradation without impacting side lobes.

(Control Unit)

Next, the control unit of the laser printer **18** including the drive circuit for driving the laser light source **211**B comprising the GaN based semiconductor laser will be described in detail.

As shown in FIG. **10**, the control unit pertaining to the present embodiment is disposed with a control circuit **80** that includes a microcomputer. The control circuit **80** is connected to a bus **88**, and an image data memories **74**, **76** and **78** are connected to the bus **88**. That is, the image data memories **74**, **76** and **78** are disposed as memories for storing image data for recording images on the printing paper **224**. The image data memory **74** is a memory that stores R-color image data, the image data memory **76** is a memory that stores G-color image data, and the image data memory **78** is a memory that stores B-color image data.

An R-purpose LD drive circuit **96**, a G-purpose LD drive circuit **98**, and a B-purpose LD drive circuit **100** are also connected to the bus **88**. The R-purpose LD drive circuit **96** and the B-purpose LD drive circuit **100** are connected through modulation circuits **90** and **92**, respectively. That is, the direct intensity of the semiconductor lasers **211**R and **211**B is modulated by modulation signals being generated by the modulation circuits **90** and **92** on the basis of image data and the modulation signals being superposed at the LD drive circuit.

An AOM drive circuit **94** is also connected to the bus **88**, and drive of the AOM **94** is controlled. That is, the laser light source **2100** is indirectly modulated by the AOM **214**G.

A polygon motor drive circuit **82** for driving a polygon motor **88** that rotatingly drives the polygon mirror **218** and a printing paper moving motor drive circuit **84** for driving a printing paper moving motor **86** for moving the printing paper **224** are also connected to the bus **88**, and each is controlled by the drive circuit **80**.

Next, operation of the laser printer **18** pertaining to the present embodiment will be described.

In a case where an image is recorded on the printing paper **224**, in order to record by scan-exposure on the printing paper **224** an image represented by image data for recording inputted from the image processor **16**, the control unit of the

laser printer **18** carries out various corrections with respect to the image data for recording and creates image data for scan-exposure on the basis of parameters for image recording inputted from the image processor **16**, and stores the created image data in the image data memories **74**, **76** and **78**.

Then, as the polygon mirror **218** of the laser printer **18** is rotated in the direction of arrow A in FIG. **3** and laser light of each color is emitted due to the laser light sources **211**R, **210**G, and **211**B providing current to the semiconductor laser, modulation signals are generated on the basis of the created image data for scan-exposure, and the amplitude of the ultrasonic wave signal (high-frequency signal) provided to the AOM **214**G in correspondence with levels of the modulation signals is altered to modulate the G laser light emitted from the AOM **214**G as diffracted light. Accordingly, the G laser light, whose intensity has been modulated in correspondence to the density of the image to be recorded on the printing paper **224**, is emitted from the AOM **214**G The G laser light is irradiated on the printing paper **224** via the flat mirror **215**, the spherical lens **216**, the cylindrical lens **217**, the polygon mirror **218**, the f θ lens **220**, the cylindrical lens **221**, the cylindrical mirror **222**, and the angled mirror **223**.

With respect to the laser light sources **211**R and **211**B, laser light is modulated by modulating current intensity applied to the laser light sources **211**R and **211**B. Therefore, R laser light and B laser light that has been modulated in correspondence to the density of an image that is to be recorded on the printing paper **224** is emitted from the laser light sources **211**R and **211**B. These laser lights are irradiated on the printing paper **224** respectively through the collimator lenses **213**, the cylindrical lens **217**, the polygon mirror **218**, the f θ lens **220**, the cylindrical lens **221**, the cylindrical mirror **222**, and the angled mirror **223**.

In accompaniment with the rotation of the polygon mirror **218** in the direction of arrow A in FIG. **3**, main scanning is effected by the irradiated position of each laser light being scanned along the direction of arrow B in FIG. **3**, sub-scanning of each laser light is effected by the printing paper **224** being conveyed at a constant speed along the direction of arrow C in FIG. **3**, and an image (latent) is recorded on the printing paper **224** by scan-exposure.

Because the laser light source **211**B pertaining to the present embodiment uses a GaN based semiconductor laser, a large amount of stray light is also emitted at the same time by the semiconductor laser, which adversely impacts the sharpness of the image to be recorded on the printing paper **224**. However, in the present embodiment, as described above, the numerical aperture NA of the collimator lens **213** is controlled.

That is, stray light emitted from the GaN based semiconductor laser is kicked in correspondence to the numerical aperture NA of the collimator lenses **213**, and the stray light is controlled by the numerical apertures of the collimator lenses **213**. Therefore, when the image to be recorded on the printing paper **224** is a striped image such as the one shown in FIG. **17**A, it is possible to control coloration between the stripes and to record an image of high sharpness.

It should be noted that, in the above-described scan-exposure, the timing at which modulation of each laser light is conducted and the timing at which the printing paper **224** is conveyed in the direction of arrow C in FIG. **3** is determined on the basis of the sensor output signal outputted from the SOS detection sensor **228**.

The printing paper **224**, on which an image has been recorded by scan-exposure, is sent to the processor **20**, where various processing such as color development, bleach-fixing, rinsing and drying is conducted. Thus, an image is formed on the printing paper **224**.

In this manner, in the laser printer **18** pertaining to the present embodiment, by setting the ratio R between the total angle ϕ of the widening angle in the median intensity of B laser light emitted from the laser light source **211**B and the total angle 2θ of the widening angle of light defining the numerical aperture NA of the collimator optical system **72** (in the present embodiment, the collimator lenses **213**) to be $2.0 \geqq R \geqq 0.58$, it is possible to control the stray light irradiated on the printing paper **224**.

Further, by defining a lower limit of the ratio R to be 0.58, a modulation range necessary for exposure can be obtained without being influenced by the side lobes.

In the embodiment described above, the ratio R is set by the numerical aperture NA of the collimator lens **213**, or by limitation of the numerical aperture NA by the opening **73** provided at the light incidence side of the collimator lens **213**. However, the invention is not limited thereto, and the total angle ϕ of the widening angle in the median intensity of the B laser light emitted by the GaN based semiconductor laser may be set by selecting the GaN based semiconductor laser so that the ratio R satisfies $2.0 \geqq R \geqq 0.58$.

It should be noted that, in the above-described embodiment, stray light irradiated on the printing paper **224** is controlled by limiting the numerical aperture NA by the opening **73** disposed at the light incident side of the collimator lenses **213** or the numerical aperture of the collimator lenses **213**. However, as shown in FIG. **11**, a luminous flux limiter **75**, such as a diaphragm resulting from a transmittance opening through which light is transmitted, may also be disposed at the position at which laser light of the collimator optical system **72** collimates. For example, as shown in FIG. **12**, when a structure is present in which a collimator lens **202** and a collimator lens **213** are successively disposed within the collimator optical system **72**, a luminous flux limiter **75** such as a transmittance opening (able to limit luminous flux by transmittance area) through which light is transmitted may be disposed at a position at which light is collimated by the collimator lens **202**. By disposing the luminous flux controller **75** in this manner, it is possible to further control stray light irradiated on the printing paper **224**. In addition to the transmittance opening shown in FIGS. **11** and **12**, a reflective mirror (able to limit luminous flux by reflectance area) **204** also be used as the luminous flux controller **75**, as shown in FIG. **13**.

Moreover, in the present embodiment, when the numerical aperture NA of the collimator lens **213** is limited so that the ratio R becomes $2.0 \geqq R \geqq 0.58$, the numerical aperture NA of the collimator lens **213** is limited by the opening **73** disposed at the light incidence side of the collimator lens **213** or by the numerical aperture of the collimator lens **213** itself. However, the present invention is not limited to the same. For example, as shown in FIG. **14**, it is also possible to dispose a numerical aperture limiter such as an angled mirror **206** at the laser light emission side of the laser light source **211**B and limit the numerical aperture NA of the collimator lens **213** by the reflectance area of the reflective mirror **204**.

Second Embodiment

Next, a second embodiment of the invention will be described. Description of structures that are the same as those described in the first embodiment will be omitted.

In the second embodiment of the invention, in contrast to the laser printer in the first embodiment, the collimator lens **213**, the limiter **200**, and the cylindrical lens **217** are successively disposed at the laser light emission side of the laser light source **211**B. Laser light emitted from the laser light source **211**B is collimated by the collimator lens **213**, and an amount of light that is predetermined in correspondence to the amount of light emitted from the laser light source **211**B is limited by the limiter **200**. The laser light is irradiated at a position that is substantially the same as the above-described predetermined position on the reflective surface of the polygon mirror **218** and reflected by the polygon mirror **218**.

It is possible to use a light filter (density filter or the like) or a half mirror as the limiter **200** to limit the light amount. Also, the limiter **200** does not have to be disposed between the collimator lens **213** and the cylindrical lens **217**. An optical system disposed above the optical path of the laser light source **211**B may be used as a limiter. For example, in order to increase reflectance of a mirror such as the polygon mirror **218**, a reflective coat or the like may be coated. It is also possible to limit the light amount even by coating a coating surface on a lens in order to limit transmittance of a lens such as the collimator lens **213**. Moreover, various kinds of limiters resulting from the optical system on the optical path of the laser light source **211**B and various kinds of limiters such as light filters and half mirrors can be used in combination.

The action of the laser printer **18** in the second embodiment of the invention is different from that of the first embodiment in the following points.

With respect to the laser light source **211**R, laser light is modulated by modulating the current intensity applied to the laser light source **211**R. Therefore, R laser light that has been modulated in correspondence to the density of the image to be recorded on the printing paper **224** is emitted from the laser light source **211**R. This R laser light is irradiated on the printing paper **224** through the collimator lens **213**, the cylindrical lens **217**, the polygon mirror **218**, the f θ lens **220**, the cylindrical lens **221**, the cylindrical mirror **222**, and the angled mirror **223**.

With respect to the laser light source **211**B, similar to the laser light source **211**R, laser light is modulated by modulating the current intensity applied to the laser light source **211**B. Therefore, B laser light that has been modulated in correspondence to the density of the image to be recorded on the printing paper **224** is emitted from the laser light source **211**B. This B laser light is irradiated on the printing paper **224** through the collimator lens **213**, the limiter **200**, the cylindrical lens **217**, the polygon mirror **218**, the f θ lens **220**, the cylindrical lens **221**, the cylindrical mirror **222**, and the angled mirror **223**.

In accompaniment with the rotation of the polygon mirror **218** in the direction of arrow A in FIG. **18**, main scanning is effected by the irradiated position of each R, G and B laser light being scanned along the direction of arrow B in FIG. **18**, sub-scanning of each laser light is effected by the printing paper **224** being conveyed at a constant speed along the direction of arrow C in FIG. **18**, and an image (latent) is recorded on the printing paper **224** by scan-exposure.

Because the laser light source **211**B uses a GaN based semiconductor laser, it has the characteristic of emitting a large amount of stray light, which adversely impacts image quality as described above.

The amount of light (InGaN based semiconductor laser (LD) or SLD laser) at the exposure surface near the 440 nm necessary to expose the color paper (the printing paper **224**), which is a silver halide photosensitive material used in digital mini-laboratories, is in the relation shown in Table 1 below when exposure resolution (dpi) and laser scanning speed are used as parameters. It should be noted that a scanning speed of 500 to 1500 m/sec is for a mini-laboratory of standard capacity, a scanning speed lower than that is for a compact low-speed machine, and a scanning speed higher than that is for a large-scale mini-laboratory.

TABLE 1

dpi	Scanning Speed (m/sec)	Exposure Surface Maximum Light Amount (μW)
600	423	14.1
600	847	28.2
600	1411	47.0
400	635	31.8
400	1270	63.5
400	2117	105.8
300	847	56.4
300	1485	99.0
300	2822	188.1

As indicated in FIG. **1**, it will be understood that the necessary exposure surface light amount in a standard mini-laboratory is 100 μW or less.

As shown in FIG. **19**, with respect to light output/drive current characteristics of a GaN based semiconductor laser, during times of low operating current, an extremely large light output of stray light is included in the ratio between light output of the collimator spot and light output of stray light. When the operating current is raised (e.g., 0.1 mW), the ratio of light output of stray light in the aforementioned ratio largely decreases in comparison to times of low operating current.

Thus, in the present embodiment, the drive current is increased and driven so that the light amount of B laser light outputted from the laser light source **211**B becomes a light amount equal to or greater than that necessary to be able to expose the printing paper **224** even if B laser light is reduced, and the limiter **200** is disposed on the optical path of B laser light emitted from the laser light source **211**B. That is, the laser light source **211**B is made to emit light at a large light amount that exceeds the light amount for exposing an image on the printing paper **224**, and the light amount of B laser light emitted from the laser light source **211**B is limited to become a light amount necessary for exposure by the limiter **200** disposed on the optical path of B laser light emitted from the laser light source **211**B, and the light is irradiated on the printing paper **224**. That is, the ratio of stray light outputted from the laser light source **211**B can be reduced as described above. Because the limiter **200** relatively limits the total light amount emitted from the laser light source **211**B, B laser light in which there is little stray light can be irradiated on the printing paper **224**.

When the laser light source **211**B is driven to simply become a light output of 0.05 mW, the light output of stray light becomes about 15 μW. In contrast, in the present embodiment, when the laser light source **211**B is driven to become a light output of 0.25 mW, the amount of light is limited by the limiter **200**, and B laser light of 20% reaches the printing paper **224**, the printing paper **224** is exposed at the light output of 0.05 mW, and a light output of about 30 μW of stray light in this case is limited to a light output of 6 μW by the limiter **200**, whereby stray light is suppressed.

Therefore, stray light irradiated on the printing paper **224** can be suppressed by disposing the limiter **200** for limiting light amount on the optical path of B laser light emitted from

the laser light source **211**B and by driving the laser light source **211**B at a drive current so that the light amount becomes a large light amount exceeding the light amount for exposing an image on the printing paper **224**.

Moreover, as described above, because the necessary exposure surface light amount in a standard mini-laboratory is 100 μW or less, in the present embodiment, the drive current is driven so that light output of 0.5 mW or more is outputted from the laser light source **211**B, and by making light loss due to the limiter **200** and the other optical system disposed on the optical path of B laser light, i.e., by making the light amount limited by the optical system 80% or more, it is possible to obtain an exposure surface light amount of 100 μW.

It should be noted that, in the above-described scan-exposure, the timing at which modulation of each laser light is conducted and the timing at which the printing paper **224** is conveyed in the direction of arrow C in FIG. **18** is determined on the basis of the sensor output signal outputted from the SOS detection sensor **228**.

The printing paper **224**, on which an image has been recorded by scan-exposure, is sent to the processor **20**, where various processing such as color development, bleach-fixing, rinsing and drying is conducted. Thus, an image is formed on the printing paper **224**.

Third Embodiment

Next, a third embodiment of the invention will be described. Description of structures that are the same as those described in the first and second embodiments will be omitted.

The laser printer in the third embodiment of the invention includes the following characteristics that are different from those of the first and second embodiments.

The collimator lens **213** and the cylindrical lens **217** are successively disposed at the laser light emission side of the laser light source **211**R. Laser light emitted from the laser light source **211**R is collimated by the collimator lens **213** and irradiated via cylindrical lens **217** at a position that is substantially the same as the above-described predetermined position on the reflective surface of the polygon mirror **218** and reflected by the polygon mirror **218**.

The collimator lens **212** and the acoustooptic modulator (AOM) **214**G that serves as an outside modulator are successively disposed at the laser light emission side of the laser light source **210**G The AOM **214**G is disposed so that laser light made incident thereon passes through an acoustooptic medium, and is connected to an AOM driver (not illustrated). When a high-frequency signal is inputted from the AOM driver, an ultrasonic wave corresponding to the high-frequency signal is propagated through the acoustooptic medium, diffraction occurs due to an acoustooptic effect acting on the laser light passing through the acoustooptic medium, and laser light of a strength corresponding to the amplitude of the high-frequency signal is emitted from the AOM **214**G as diffracted light. In short, the AOM is a light modulator that uses an acoustic diffraction phenomenon in which the refractive index of material is altered by sound waves and an optical diffraction grating is created.

A collimator lens **44** and a reflective diffraction grating **46** that serves as a diffraction unit are successively disposed at the laser light emission side of the laser light source **211**B. The reflective diffraction grating **46** diffracts laser light in a predetermined direction using an interference effect and reflects stray light other than laser light in a direction different from the direction in which the laser light is diffracted. Light emitted from the laser light source **211**B is collimated by the collimator lens **44** and reflected on a surface of the reflective diffraction grating **46**. As shown in FIG. **21**, laser light **48** laser-oscillated at a predetermined wavelength and EL light **49** are emitted from the laser light source **211**B. The laser light **48** is indicated by the solid lines and the EL light **49** is indicated by the dotted lines. Whereas the emission angle of the laser light **48** is within a predetermined range and the laser light **48** is light in which the wave front and wave length are uniform, the EL light **49** is incoherent light in which the emission position, direction, and wave length are random. For this reason, when the laser light **48** and the EL light **49** are irradiated on the surface of the reflective diffraction grating, the laser light **48** oscillated at a predetermined wavelength is diffracted in a predetermined direction at the reflective diffraction grating **46**, but the EL light **49** is reflected as it is virtually without being diffracted. Thus, it is possible to separate and remove the EL light included in the output light of the laser light source **211**B.

The collimator lens **213**, the cylindrical lens **217**, and the polygon mirror **218** are successively disposed at the diffracted light emission side of the reflective diffraction grating **46**. B laser light emitted as diffracted light from the reflective diffraction grating **46** is collimated by the collimator lens **213** and irradiated via the cylindrical lens **217** at a position that is substantially the same as the above-described predetermined position on the reflective surface of the polygon mirror **218** and reflected by the polygon mirror **218**.

(Detailed Structure of the 440 nm Oscillation Wavelength Semiconductor Laser)

Next, an example of the structure of the 440 nm oscillation wavelength GaN LD used in the laser light source **211**B in the third embodiment of the invention will be described in detail. A laminate structure of the GaN LD is shown in FIG. **22**.

In the GaN LD shown in FIG. **22**, a low-defect n-GaN substrate layer **52**, and n-GaN buffer layer **54** (silicon (Si)-doped, thickness of 5 μm), an n-In 0.1 Ga 0.9 N buffer layer **56** (silicon (Si)-doped, thickness of 0.1 μm), an n-A 10.1 Ga 0.9 N cladding layer **58** (silicon (Si)-doped, thickness of 0.45 μm), an n-GaN guide layer **60** (silicon (Si)-doped, thickness of 0.08 μm), an undoped active layer **62**, a p-GaN guide layer **64** (magnesium (Mg)-doped, thickness of 0.08 μm), a p-A 10.1 Ga 0.9 N cladding layer **66** (Mg-doped, thickness of 0.45 μm), and a p-GaN capping layer **68** (Mg-doped, thickness of 0.25 μm) are successively laminated on a sapphire substrate **50**.

The active layer **60** is a double quantum well structure in which undoped In 0.05 Ga 0.95 N (thickness of 10 nm), undoped In 0.23 Ga 0.77 N quantum well layer (thickness of 3 nm), undoped In 0.05 Ga 0.95 (thickness of 5 nm), undoped In 0.23 Ga 0.77 N quantum well layer (thickness of 3 nm), undoped In 0.05 Ga 0.9 N (thickness of 10 nm), and undoped A 10.1 Ga 0.9 N (thickness of 10 nm) are laminated in this order.

This laminate has a height (H**3**) of about 100 μm, a width (W**2**) of about 300 μm, and is ablated to a depth at which the n-GaN buffer layer **54** is exposed, whereby a post-shaped mesa is formed. The height (H**2**) of the mesa is 3 to 5 μm. The mesa is ablated to a depth at which the p-A 10.1 G 0.9 N cladding layer **66** is exposed, whereby a ridge stripe is formed. The height (H**1**) of the ridge portion is about 0.9 μm, and the width (W**1**) of the ridge portion is about 1.7 μm.

An upper surface of the exposed p-A 10.1 G 0.9 N cladding layer **66** and side surfaces of the p-GaN capping layer **68** are covered by a silicon nitride (SiN) film **70**. A p-side electrode **72** is formed on the p-GaN capping layer **68** so as to contact the exposed portion of the p-GaN capping layer **68**, and an n-side electrode **74** is formed on the exposed n-GaN buffer layer **54**. In this LD, when the current flows from the p-side electrode **72** to the n-side electrode **74**, a current path is sandwiched by the ridge stripes and effectively injected into the active layer **62**, whereby 440 nm oscillation wavelength laser light is removed from the edges.

Next, the manufacturing process of the LD of the above-described structure will be simply explained. First, a low-defect n-GaN substrate layer **52** is formed on a c surface of a sapphire substrate **50** by a method disclosed in the literature (S. Nagahama, et. al., Jpn. J. Appl. Phys. Vol. 39, No. 7A, p. L647 (2000)).

Next, using metal organic chemical vapor deposition (MOCVD), an n-GaN buffer layer **54**, an n-In 0.1 Ga 0.9 N buffer layer **56**, an n-A 10.1 Ga 0.9 N cladding layer **58**, an n-GaN guide layer **60**, an undoped active layer **62**, a p-GaN guide layer **64**, a p-A 10.1 Ga 0.9 N cladding layer **66**, and a p-GaN capping layer **68** are successively laminated.

Next, the substrate is removed from the growth chamber and part of the laminate is removed by reactive ion beam etching (RIBE) using chlorine ions until the p-A 10.1 Ga 0.9 N cladding layer **66** is exposed, whereby ridge stripes having a width of about 1.7 μm are formed. The p-A 10.1 Ga 0.9 N cladding layer **66** is removed to a depth of 0.1 μm from the surface of the p-GaN guide layer **64**.

Next, the surface of the exposed p-A 10.1 Ga 0.9 N cladding layer **66** and the surface of the p-GaN capping layer **68** are covered with an SiN film **70** by plasma CVD, a resist mask is formed by photolithography, and the SiN film formed on the ridge is selectively removed by etching. Thereafter, p-type impurities are activated by heating in a nitrogen gas atmosphere.

Next, the epilayer other than portions including light emission regions (portions unnecessary for structuring the laser) is removed by RIBE using chlorine ions until the n-GaN buffer layer **54** is exposed, whereby a post-shaped mesa is formed.

Next, Ni/Au is successively vacuum-evaporated on the exposed surface of the p-GaN capping layer **68** and Ti/Al/Ti/Au is successively vacuum-evaporated on the exposed surface of the n-GaN buffer layer **54**, and each are annealed in a nitrogen atmosphere to form ohmic electrodes. Thus, the p-side electrode **72** is formed on the p-GaN capping layer **68**, and the n-side electrode **74** is formed on the n-GaN buffer layer **54**. Finally, resonator ends are formed by cleavage. Thus, the LD is completed.

It should be noted that it is also possible to use a sapphire substrate of an insulator or a conductive silicon carbide (SiC) substrate in place of the sapphire substrate on which the low-defect n-GaN substrate layer **52** is formed. Moreover, it is also possible to reduce translocation of oscillation stripe regions, as disclosed in the literature (Matsushita, *Optronics,* No. 1, p. 62 (2000)), by forming each layer of the laminate using epitaxially lateral over growth (ELOG) rather than MOCVD.

The relation between the drive current and light intensity (light output) on the printing paper resulting from light emitted from the laser light source **211**B which is the B laser light source, is shown in FIG. **23**. As indicated by the solid line, in the present embodiment in which the reflective diffraction grating is used, light intensity at the printing paper resulting from EL light is largely reduced. Exposure of the printing paper is sufficient at a power of about 0.1 mW, but light intensity on the printing paper resulting from the EL light is extremely low even in low exposure intensity regions in which the light intensity on the printing paper in the laser spot becomes about 0.1 mW. The relation between the drive current and light intensity on the printing paper when light emitted from the laser light source **211**B is made incident directly on the collimator lens **214** without using the reflective diffraction grating is indicated by the dotted lines. Even compared with this, it will be understood that, in the present embodiment, light intensity on the printing paper resulting from the EL light was largely reduced by about 1/10.

As described above, in the present embodiment, the GaN LD was used in the B laser light source (laser light source **211**B). Because EL light included in the output light of the GaN LD can be largely reduced using the reflective diffraction grating, a pattern in which the contour thereof is unclear on the printing paper due to the EL light is not formed. For this reason, it is possible to expose the printing paper at a laser spot whose contour is sharp, and it possible to obtain a high-resolution image having excellent sharpness.

It is possible for the optical system of the laser printer to be simplified by directly modulating the GaN LD and miniaturize the entire device. It is also possible to dispose an external modulator such as an electro optic modulator (EOM) or an AOM at the diffracted light emission side of the reflective diffraction grating and externally modulate the GaN LD instead of direct modulation.

Fourth Embodiment

Next, a fourth embodiment of the invention will be described.

The digital laboratory system pertaining to the fourth embodiment is the same as the digital laboratory system pertaining to the third embodiment, except that in the optical system of the laser printer, the B-color laser light source is not directly modulated, but laser light is modulated by a grating light valve (GLV) of a reflective diffraction grating type disposed with a light modulating function as a diffraction unit. Therefore, description of the same parts will be omitted, and description will be given only of the different points.

As shown in FIG. **24**, the collimator lens **44** and a GLV **80** are successively disposed at the laser light emission side of the laser light source **211**B comprising the GaN LD. The GLV **80** is predisposed at a predetermined angle (e.g., 90°) with respect to the optical axis of the collimator lens **213**, so that light diffracted at the GLV is made incident on the collimator lens **213** disposed at the emission side.

Light emitted from the laser light source **211**B is collimated by the collimator lens **44** and irradiated on a surface of the GLV **80**. When the laser light **48** and the EL light **49** are irradiated on the surface of the GLV **80**, the laser light **48** that has been oscillated at a predetermined wavelength is modulated at the GLV **80** in correspondence to an input signal as described later and diffracted in a predetermined direction, and the EL light **49** is reflected as it is without hardly being diffracted and without relation to the input signal. Thus, it is possible to separate and remove the EL light included in the output light of the laser light source **211**B.

Referring to FIGS. **25**A to **25**C, description will be given here of the structure and operating principle of the GLV **80**. The GLV **80** is a spatial light modulator (SLM) of the micro electro mechanical systems (MEMS) type as disclosed in, for example, U.S. Pat. No. 5,311,360. As shown in FIG.

25A, plural gratings are sequentially disposed in one direction. Plural (e.g., six) ribbon-like micro bridges **84** that serve as movable gratings are disposed on a substrate **82** of the GLV **80** comprising silicon or the like. Plural slits **86** are formed by arranging the micro bridges **84** in parallel. The micro bridges **84** are spaced a predetermined distance from the substrate **82**. As shown in FIGS. **25**B and **25**C, the undersurface of each micro bridge **84** facing the substrate **82** comprises a flexible beam **84***a* formed of silicon nitride (SiNx) or the like, and the upper surface of each micro bridge **84** comprises a reflective electrode film **84***b* formed of single layer of metallic film such as aluminium (or gold, silver, copper, etc.).

The GLV **80** is drivingly controlled by turning on and off a voltage applied between the micro bridges **84** and the substrate **82**. When the voltage applied between the micro bridges **84** and the substrate **82** is turned on, electrostatic attraction is generated between the micro bridges **84** and the substrate **82** by an electrostatic induced charge, whereby the micro bridges **84** bend towards the substrate **82**. When the applied voltage is turned off, the micro bridges **84** stop bending and separate from the substrate **62** by elastic return. Therefore, by alternatingly disposing the micro bridges **84** to which the voltage is applied, it is possible to create a diffraction grating by the application of the voltage.

When the voltage is not applied to the micro bridges **84** (when the GLV is not driven), the height of the reflective surface of the micro bridges **84** is all uniform, and reflected light is regularly reflected without any optical path difference. When the voltage is applied to one micro bridge **84** (when the GLV is driven), the center of the micro bridge **84** bends according to the above-described principle, and the reflective surface becomes one in which there are alternating differences in height. When laser light is made incident on this reflective surface, optical path difference arises in light reflected at the micro bridges **84** that are not bent, and a light diffraction phenomenon occurs. Intensity I_{1st} of first order diffracted light is dependent on the generated optical path difference and can be represented by the following equation. In this case, intensity of the diffracted light becomes the greatest when $\lambda/2$ as the optical path difference.

$$I_{1st}=I_{MAX}\sin(2\pi/\lambda) \qquad \text{(Equation 1)}$$

The GLV **80** is connected to a GLV driver (not illustrated), and when pulse modulation signal is inputted from the GLV driver, the GLV **80** is turned on or off in correspondence to the input signal. That is, when the signal is off, the GLV is not driven, and light made incident on the GLV **80** is reflected at a reflectance angle that is the same as the incidence angle and becomes 0 order reflected light. This 0 order reflected light is removed from the incidence optical path of the collimator lens **213** disposed at the emission side using, for example, a slit panel. When the signal is on, the GLV is driven, and light made incident on the GLV **80** is reflected (diffracted) in a predetermined direction.

As a result of investigating the relation between the drive current and light intensity on the printing paper resulting from light irradiated from the light source **211**B, which is the B laser light source, it was confirmed that light intensity on the printing paper resulting from the EL light was largely reduced even in the present embodiment in which the GLV was used as the diffraction unit.

As described above, in the present embodiment, the GaN LD was used in the B laser light source (laser light source **211**B). Because EL light included in the output light of the GaN LD can be largely reduced using the GLV, a pattern in which the contour thereof is unclear on the printing paper due to the EL light is not formed. For this reason, it is possible to expose the printing paper at a laser spot whose contour is sharp, and it possible to obtain a high-resolution image having excellent sharpness.

Because the GaN LD is continuously oscillated and externally modulated by the GLV without being modulated by altering the current intensity applied to the GaN LD, it is possible to always activate the GaN LD in a high light output state and to reduce EL light. Moreover, because the GLV functions as both a diffraction optical modulator and as an external modulator, the number of optical parts decreases and optical alignment becomes simple.

It should be noted that an external modulator such as an electro optic modulator (EOM) or an AOM may be disposed at the diffracted light emission side of the GLV. Also, the GaN LD may be directly modulated using only the GLV as the reflective diffraction grating.

Fifth Embodiment

The digital laboratory system pertaining to the fifth embodiment is the same as the digital laboratory system pertaining to the third embodiment, except that in the optical system of the laser printer, the B-color laser light source is not directly modulated, but laser light is modulated by an acoustooptic modulator (AOM) that is a transmittance diffraction modulator disposed with a light modulating function as a diffraction unit. Therefore, description of the same parts will be omitted, and description will be given only of the different points.

As shown in FIG. **26**, the collimator lens **44** and an AOM **88** are successively disposed at the laser light emission side of the laser light source **211**B comprising the GaN LD. Light emitted from the laser light source **211**B is collimated by the collimator lens **44** and irradiated on a surface of the AOM **88**. The AOM **88** is disposed so that laser light made incident thereon is transmitted through an acoustooptic medium, and is connected to an AOM driver (not illustrated).

As shown in FIG. **27**, when a modulation signal is inputted from the AOM driver (not illustrated), the laser light **48** that has been oscillated at a predetermined wavelength from the laser light source **211**B is modulated at the AOM **88** in response to an input signal due to an acoustooptic effect and diffracted in a predetermined direction. The EL light **49** is transmitted as it is, hardly without being diffracted and without relation to the input signal. Also, because the EL light **49** is light that is originally spatially dispersed, it is not made incident at modulation regions in which the thickness is only substantially 0.5 mm or less. Thus, it is possible to separate and remove most of the EL light included in the output light of the laser light source **211**B.

A flat mirror **90** is disposed at the diffracted light emission side of the AOM **88**. A spherical lens **92**, a cylindrical lens **217**, and a polygon mirror **218** are successively disposed at the laser light emission side of the flat mirror **90**. B laser light emitted as diffracted light from the AOM **88** is reflected by the flat mirror **90**, reflected to a predetermined position on a reflective surface of the polygon mirror **218** via the spherical lens **92** and the cylindrical lens **217**, and then reflected at the polygon mirror **218**.

The substantial thickness of the AOM used as the diffraction unit is about 0.05 mm to 1.0 mm. When a highly sensitive silver halide photosensitive material is used, it is preferable for the thickness to be 0.5 mm or less in order to obtain a high-resolution image. The reason the refractive index of the material is altered by sound waves in the AOM

and an optical diffraction grating is formed is believed to stem from the thickness being 1.0 mm or less from the surface. When the substantial thickness of the AOM is roughly less than 0.05 mm, a sufficient diffraction effects cannot be obtained. As shown in FIG. **27**, diffraction efficiency reaches a maximum as a result of the electric field being made directly incident on the AOM modulator. The electric field is formed so that it faces a direction parallel to a bonded surface of the laser modulator. Therefore, it is preferable to dispose the laser modulator and the optical system so that the electric field is substantially orthogonal to the AOM modulator.

As described in the third embodiment, the laser light source **211**B is a GaN LD comprising the sapphire substrate **50** having successively disposed thereon the n-GaN substrate layer **52**, the n-GaN buffer layer **54**, the n-$In_{0.1}Ga_{0.9}N$ buffer layer **56**, the n-$Al_{0.1}Ga_{0.9}N$ cladding layer **58**, the n-GaN guide layer **60**, the undoped active layer **62**, the p-GaN guide layer **64**, the p-$Al_{0.1}Ga_{0.9}N$ cladding layer **66**, and the p-GaN capping layer **68**. Each semiconductor layer can be formed by epitaxial growth.

As a result of investigating the relation between the drive current and light intensity on the printing paper resulting from light irradiated from the light source **211**B, which is the B laser light source, it was confirmed that light intensity on the printing paper resulting from the EL light was largely reduced even in the present embodiment in which the AOM was used as the diffraction unit.

As described above, in the present embodiment, the GaN LD was used in the B laser light source (laser light source **211**B). Because it is possible to largely reduce the EL light included in the output light of the GaN LD using the AOM, a pattern in which the contour thereof is unclear on the printing paper due to the EL light is not formed. For this reason, it is possible to expose the printing paper at a laser spot whose contour is sharp, and it possible to obtain a high-resolution image having excellent sharpness.

Because the GaN LD is continuously oscillated and externally modulated by the AOM without being modulated by altering the current intensity applied to the GaN LD, there is the advantage that removal efficiency of the EL light is increased by the EL light being kicked at the AOM. Moreover, because the AOM functions as both a diffraction optical modulator and as an external modulator, the number of optical parts decreases and optical alignment becomes simple.

What is claimed is:

1. An image exposure device that uses a laser beam to scan-expose an image on photosensitive material, the image exposure device comprising:

a GaN based semiconductor laser for emitting light that includes a laser beam and emission light other than the laser beam;

a drive for driving the GaN based semiconductor laser so that the light is emitted at an amount that is equal to or greater than an amount necessary to be able to expose the photosensitive material even if the light is reduced; and

a limiter for limiting the light emitted from the GaN based semiconductor laser so that the light irradiated onto the photosensitive material is of an amount necessary for exposure, the limiter being disposed in an optical path of the light that is emitted from the GaN based semiconductor laser and irradiated onto the photosensitive material.

2. The image exposure device of claim **1**, wherein the drive drives the GaN based semiconductor laser at 0.5 mW or greater, and the limiter limits at least 80% of the light emitted from the GaN based semiconductor laser.

3. The image exposure device of claim **1**, wherein the limiter comprises at least one of

a density filter,

a half mirror,

a coated surface that is coated on the lens disposed on the optical path and limits the light, and

a reflective coat that is coated on a mirror disposed on the optical path.

4. The exposure device of claim **1**, wherein the exposure is conducted at an exposure resolution of 300 to 600 dpi.

5. The exposure device of claim **1**, wherein the exposure is conducted at a scanning speed of 500-1500 in/sec.

6. A laser exposure device comprising:

a semiconductor laser that comprises gallium nitride and emits stray light; and

a diffraction unit for diffracting the laser light emitted from the semiconductor laser in a predetermined direction that is different from that of the stray light,

wherein the diffraction unit diffracts the laser light emitted from the semiconductor device and spatially modulates the intensity of the diffracted light in correspondence to image data.

7. The laser exposure device of claim **6**, wherein the diffraction unit spatially modulates the intensity of the diffracted light by controlling a gradient index or a shape of a diffraction groove.

8. The laser exposure device of claim **7**, wherein the diffraction unit spatially modulates the intensity of the diffracted light by controlling the gradient index, and thickness of a portion at which the gradient index is formed is 0.05 mm to 1.0 mm.

9. The laser exposure device of claim **6**, wherein the semiconductor laser is disposed so that an electric field faces a direction that is substantially orthogonal to an effective diffraction grating surface of the diffraction unit.

10. The laser exposure device of claim **6**, further comprising a spatial modulator for spatially modulating the intensity of the diffracted light, the spatial modulator being disposed between the semiconductor laser and a photosensitive material.

11. The exposure device of claim **10**, wherein the modulator modulates the diffracted light in correspondence to image data.

12. The device of claim **11** wherein the modulator modulates diffracted light to the photosensitive medium to form an image on the photosensitive material.

13. The exposure device of claim **6**, said laser emitting laser light towards a photosensitive material to scan expose the photosensitive material.

14. The exposure device of claim **13**, wherein the exposure is conducted at an exposure resolution of 300 to 600 dpi.

15. The exposure device of claim **13**, wherein the exposure is conducted at a scanning speed of 500-1500 m/sec.

16. The device of claim **6**, wherein the spatial modulation is in correspondence to image data to be formed on a photosensitive material.

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